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Communicating Uncertainty During Public Health Emergency Events: A Systematic Review

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Abstract

To answer the question, *What are the best ways to communicate uncertainties to public audiences, at-risk communities, and stakeholders during public health emergency events?* we conducted a systematic review of published studies, grey literature, and media reports in English and other United Nations (UN) languages: Arabic, Chinese, French, Russian, and Spanish. Almost 11,500 titles and abstracts were scanned of which 46 data-based primary studies were selected, which were classified into four methodological streams: Quantitative-comparison groups; Quantitative-descriptive survey; Qualitative; and Mixed-method and case-study. Study characteristics (study method, country, emergency type, emergency phase, at-risk population) and study findings (in narrative form) were extracted from individual studies. The findings were synthesized within methodological streams and evaluated for certainty and confidence. These within-method findings were next synthesized across methodological streams to develop an overarching synthesis of findings. The findings showed that country coverage focused on high and middle-income countries in Asia, Europe, North America, and Oceania, and the event most covered was infectious disease followed by flood and earthquake. The findings also showed that uncertainty during public health emergency events is a multi-faceted concept with multiple components (e.g., event occurrence, personal and family safety, recovery efforts). There is universal agreement, with some exceptions, that communication to the public should include explicit information about event uncertainties, and this information must be consistent and presented in an easy to understand format. Additionally, uncertainty related to events requires a distinction between uncertainty information and uncertainty experience. At-risk populations experience event uncertainty in the context of many other uncertainties they are already experiencing in their lives due to poverty. Experts, policymakers, healthcare workers, and other stakeholders experience event uncertainty and misunderstand some uncertainty information (e.g., event probabilities) similar to the public. Media professionals provide event coverage under conditions of contradictory and inconsistent event information that can heighten uncertainty experience for all.

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Keywords: Uncertainty; Risk communication; Disaster communication; Public health emergency events

Highlights

- Coverage of published studies, grey literature, media reports from all United Nations languages (Arabic, Chinese, English, French, Russian, Spanish).
- Synthesis of findings across four methods: Quantitative-comparison groups; Quantitative-descriptive survey; Qualitative; and Mixed-method and case study.
- Uncertainty is related to multiple facets, and is both uncertainty information conveyed in a message as well as uncertainty experienced.
- Public often experiences uncertainty due to lack of information; for its reduction, it actively seeks information from all available sources.
- Public should receive explicit, consistent, clearly understood uncertainty information speedily from authorities.
- Uncertainty information leads uniformly to desirable results for the public but for some communities it may sometimes cause negative outcomes.
- At-risk communities receive messages containing uncertainty information in lives that are already filled with many uncertainties due to poverty.
- Stakeholders such as experts, policy makers, healthcare workers, and media professionals experience uncertainty and process uncertainty information similar to the public.

Content

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1.0 INTRODUCTION

1.1 Background

Communication during a public health emergency event is a complex process. As described by the World Health Organization (WHO), risk communication is "the process by which national and local government authorities provide information to the public in an understandable, timely, transparent and coordinated manner before, during and after a crisis; also promotes effective exchange of information and opinion among scientists, public health and veterinary experts during the alert phase to better assess, manage and coordinate preparedness and response activities" (WHO, 2012, p. xii). The WHO also refers to it as the real-time exchange of information, advice, and opinions between experts and/or officials and/or the publics who face a threat/ hazard to their survival, health, or economic or social wellbeing (WHO, 2015). Emergency public health risk communication is generally distinguished from non-emergency public health risk communication exchanges by a combination of the following characteristics: A perception of a fast emerging public health threat; a dramatically increased demand for information to protect health that often outstrips the ability of health authorities to provide it; a need to communicate with potentially at-risk populations before recommendations are certain; and a rapidly evolving situation in which information about the health threat and how to prevent its continuation or spread is incomplete and changing (Reynolds, 2002; Reynolds & Seeger, 2005).

A public health emergency event, such as an earthquake, wildfire, flood, and emergent infectious disease, is usually characterized as having four major phases (Reynolds, 2002; Reynolds & Seeger, 2005): Preparation; onset; containment, which includes the peak of the emergency event; and recovery. Another characterization, also with four phases, but conceptualized slightly differently, includes: Prevention; readiness/ preparedness; response; and recovery. A fifth phase, evaluation, generally follows the recovery phase although it commonly occurs along with the earlier four phas-

es as well.

Communication with the publics during public health emergency events is a complex process involving multiple stakeholders. The messages from authorities to the general public, specific communities, and other stakeholders, must be carefully designed to successfully influence health protection behaviors. In particular, messages from authorities during the course of an emergency event must thoughtfully convey the uncertainties related to the scientific evidence and what is known about the impact and progression of the event. This becomes even more important as a key characteristic of such an event is the uncertainty the public experiences during the course of the event. Additionally, public health emergency events tend to be both local and regional and even global problems; thus, to fully know how to successfully communicate uncertainties in these situations, the political, cultural, and socioeconomic context in which the messages are received and understood must also be considered.

1.2 Objective

The WHO commissioned a systematic review of the extant literature from multiple methodologies (quantitative, qualitative, mixed-methods) on best practices for conveying uncertainties during emergency health risk communication. Specifically, the objective of the systematic review was to address the following question: What are the best ways to communicate uncertainties to public audiences, vulnerable communities, and stakeholders? To answer the question, we looked at the broader phenomenon of interest of communication and uncertainties inherent in events and emergencies with public health implications. To foreground the phenomenon of interest that could potentially be measured, observed, or described in affected populations (publics, communities, stakeholders, etc.), we focused on strategies and tactics that were effective, or in the absence of evidence of an effect, appeared to work best to manage, contain, or bring about increase/ decrease in uncertainty.

The focus for the systematic review were multiple-methods data from field studies of populations that directly experienced a relevant public health emergency event. Of interest were also data from studies of populations who may be likely to be affected by a relevant public health emergency event, particularly studies that focused on questions promoting individual preparedness for such events. Also of some interest were data from studies that addressed how organizations, predominantly government organizations or individuals employed by governments, respond to or work to develop risk communication messages. We not only sought studies that had comparison groups, but also included studies that examined concepts/ variables that may have an association with the concepts/ variables contained in the question and phenomena of interest, seeing these concepts/ variables to be potentially associated with uncertainty to find out what works and for whom and in what contexts.

2.0 METHOD[1]

2.1 Process Design for Evidence Synthesis

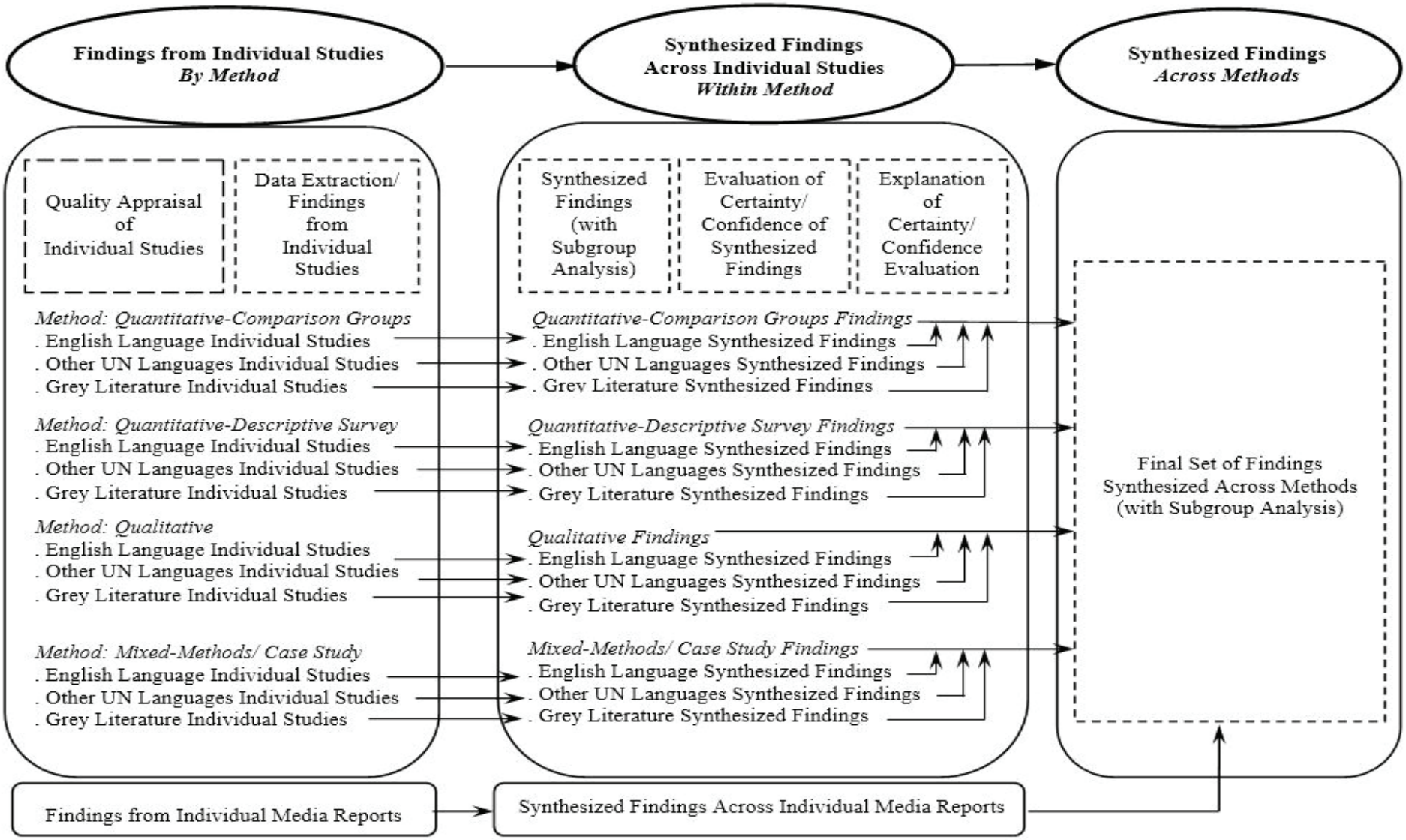
The process design for the multiple-methods evidence synthesis for the review is presented in Figure 1. Findings were extracted only from data-based primary studies. The design shows that the findings were grouped and processed within the type of study methodology stream and then brought together in an overarching synthesis of the findings across the methodology streams. Details of the process are presented below.

2.2 Determining Study Methodology of Data-based Primary Studies

We started with the following categories for data-based primary studies: Quantitative randomized control trials; qualitative (ethnographic research, case studies, process evaluations, and mix-methods designs); mixed-method stud-

[1] The present systematic review is part of a larger WHO sponsored project. The method presented here is identical across all the studies stemming from this project.

Figure 1. Process Design of Synthesis of Evidence from Data-based Primary Studies



ies (combining different types of designs to explore a phenomenon of interest); observational and cross-sectional surveys; and grey literature reports. Using the above methodological groupings as a starting point, we initially identified five methodological streams that best covered the method types found in the primary studies selected for the review:

• Quantitative – randomized group comparison and non-randomized group comparison.

• Quantitative – descriptive survey and similar designs.

• Qualitative – open-ended questionnaire survey, interview, focus group, ethnography/ participant observation, and textual analysis.

• Mixed-method – use of both quantitative and qualitative methods, where the different methods usually address different hypotheses and/ or research questions.

• Case study – use of several methods, where usually all methods address the same research question and focus on one particular event/ person/ location.

After a more in-depth perusal of the mixed-method and case study article/ reports, we did not find any appreciable methodological differences as both types utilized quantitative and qualitative methods with similar procedures. In consultation with the WHO methodologist consultant, we combined these two methodological streams. Thus, we ended up with the following four methodological streams:

• Quantitative-Comparison Groups (QN-CG)

• Quantitative-Descriptive Survey (QN-DS)

• Qualitative (QL)

• Mixed-Method and Case Study (MM, CS).

2.3 English and Other United Nations Languages

The primary search was for literature in the English language. Additionally, we conducted searches for studies published in the other United Nations (UN) languages as well, which included Arabic, Chinese, French, Russian, and Spanish.

As seen from Figure 1, we followed the same process for both English and other UN languages articles/ reports for data extraction from individual studies and synthesis of findings within methodological streams. That is, the individual studies from Arabic, Chinese, French, Russian, and Spanish were grouped into the four methodological streams, irrespective of the language, after which synthesized findings were generated within each methodological stream.

We did not completely translate Arabic, Chinese, French, Russian, and Spanish language studies into English. Portions of the studies were translated into English as needed to meet the requirements of the review. As the other UN language findings from individual studies came from studies that were only partially translated into English, we treated these findings as a separate "sub-stream" at the time of synthesis of findings within methodological streams.

2.4 Information Sources for Literature Search

We conducted a search for published primary studies using the University Library Summon function, which indexes all holdings in the library, Google Scholar, and general Google search. We also searched within individual databases including: Communication and Mass Media Complete (CMMC); Cumulative Index of Nursing and Allied Health Literature (CINAHL); CINAHL Complete; Elsevier; JSTOR; PsychInfo; PubMed/Medline-National Library of Medicine (NLM); Web of Science; and WHO databases.

Native readers of Arabic, Chinese, French, Russian, and Spanish who were fluent in English conducted the search for non-English language primary studies. In addition to the information sources noted above, the following sources were also searched for each language: Arabic, Al-Manhal, and Dar-Al-Manduma; Chinese, CNKI (China National Knowledge Infrastructure), and Wanfang Patent Database; French, Archive ouverte UNIGE, Cairn.info, Government of Canada publications, HAL archives ourvertes, La Houille Blanc, Persee.fr, and Revues.org; Russian, Cyberleninka.ru, Mgimo.ru/library/ehd, Msu.ru/info/struct/dep/library, and Nbmgu.ru; and Spanish, CONACYT, Cuiden, and Public Health Institute Mexico. In addition, persons familiar with non-English language publications were suggested by the WHO and they were solicited for suggestions for relevant studies.

The search for grey literature in all languages used Google Scholar and general Google search as the main information sources. In addition, an experienced librarian at the National Hazards Center library at the University of Colorado-Boulder, United States conducted a search specifically for grey literature. The search was conducted in close consultation with a team member who was physically present on location.

2.5 Literature Search Strategy, Search Terms, and Search Inclusion and Exclusion Criteria

We adopted a two-phase strategy for literature searching. In the first phase, we did a general search that was intentionally broad in scope. In the second phase, a search focused narrowly on the objective of the present review was conducted.

We used the search terms shown in Table 1. Not all terms worked in all databases; therefore, thesauri were consulted for each database to find synonyms, if they existed, for each term, or any functionality that allowed the word to be "exploded" or "expanded."

The following broad inclusion criteria were used in the search for literature to capture empirical research of all methodological types:

• Research related to the practice of risk communication and the process of disaster management with no preference for any specific emergency or health hazards.

• Research within the viewpoint or scope set by the risk communication field related to: trust, uncertainty, communities, health, misinformation, health protection, media (including social media), messages, and stakeholders.

The following exclusion criteria were used in the search for literature to keep a focus on public dissemination of uncertainty information:

• Research in organizational risk communication and disaster management such as technology failures.

• Research outside of the specified scope of the study, such as laboratory studies and those related to chronic disease, lifestyle, or personal living/ attributes (such as personal health, mental health, etc.).

• Studies published before 2003. This was a WHO stipulation based on a need for current research only.

2.6 Article/ Report Selection

The hits generated by the literature search process were narrowed to select data-based primary articles and reports. The general process for selection of the articles/ reports for all languages was in several steps that were in two stages, broadly conforming to the Preferred Reporting Items for Systematic Reviews and Analyses (PRISMA) process (Moher, Liberati, Tetzlaff, Altman, The PRISMA Group, 2009). After initial hits were pulled through the searches, the articles were screened for relevance to the review topic and objective at each stage. In the first stage:

• The hits obtained using a search were scanned by reading their title and abstract or summary to assess relevance to risk communication during disaster/ emergency events;

• After scanning, the hits that were judged as related to risk communication during disaster/ emergency events were quickly read as full-texts and downloaded if found still broadly related;

• The downloaded full-texts were read carefully, and if found related to the objective and phenomena of interest of the present review, were selected. These included, both academic and grey literature, data-based studies, reviews, guidelines, and media reports.

In the second stage:

• The full-texts of the selected articles and reports were again read and this time categorized as a data-based primary study or not. This included the grey literature.

• If an article/ report was a data-based primary study, it was further judged for different levels of relevancy to the review objective and phenomena of interest (see Lewin et al., 2015 and Noyes et al., 2018, for details of the relevancy criteria). Studies were judged to have direct relevance (i.e., directly mapped onto phenomenon of interest); indirect relevance (i.e., corresponded with some aspects of the phenomenon of interest); partial relevance (i.e., a part of the issue of interest or population was addressed but not all); or unclear relevance (i.e., unclear whether underlying data were relevant) with the review topic. A data-based study that was judged as directly, indirectly, partially, or uncertainly relevant (as opposed to not relevant at all) was selected for extraction of its key findings. *Only these relevant (direct, indirect, partial, unclear) primary study articles/ reports were used to generate the systematic review for this report.* These included studies used quantitative, qualitative, mixed-method, and case study methods.

To summarize, the article/ report selection process occurred in two broad stages. In the first stage, all literature that was related to disaster/ emergency risk communication, and review objective and phenomena of interest was selected. In the second stage, this literature was narrowed to select only relevant data-based primary study articles/ reports using quantitative, qualitative, mixed-method, and case study methodologies.

The first stage of the search and selection for English language articles/ reports was conducted by an experienced librarian with subject-matter expertise in the discipline of communication. Two training and norming sessions were

conducted with the librarian. The second stage selection was done by all primary members of the research team, who had gone through a training and norming session. For ambiguous cases, decisions were made through discussion among the primary research team members. Both the first and second search and selection stages for other UN languages were done by fluent readers and writers of Arabic, Chinese, French, Russian, and Spanish who were also fluent in English. Four norming and training sessions were conducted with this group in a group setting. In addition, individual training sessions were provided as needed.

2.7 Quality Appraisal of Selected Individual Studies

The individual data-based primary studies selected for the review were appraised for their quality using available tools. Quantitative control/ comparison groups studies were individually appraised using the Effective Practice and Organisation of Care (EPOC) (2015) risk of bias tool. This tool provides nine criteria for assessing randomized control trials, non-randomized control trials, and control before-after studies. Detailed information on the definitions of levels of risk used in this tool is available in section 12.2.2 of the Cochrane Handbook (Higgins & Green, 2011).

Quantitative descriptive survey studies were individually appraised using an adapted version of Davids and Roman's (2014) quality appraisal criteria. This tool assessed on a 0 to 1 scale (0-not reported, 1-reported) the following areas: sampling, response rate, validity and reliability, sources of data, content and focus of study, and relevancy to the corresponding question. Final ratings were determined by percentage, as noted in the appraisal tool: weak (0-33.9%), moderate (34-66.9%), and strong (67-100%). We used these scores as indicators and not as a hard rule, and more importantly the specific methodological weaknesses that were identified were considered in relation to how they could potentially impact on findings for the appraisal.

Qualitative studies were individually appraised using Critical Appraisal Skills Programme (CASP) (2013) checklist. Areas of the study appraised by CASP include appropriateness of qualitative methodology, data collection, relationship between research and participants, ethics, rigor of data analysis, clarity of findings, and value of research. Each area in CASP is assessed using "yes," "no," or "can't tell." Studies received a final rating of "high" (no significant flaws), "moderate" (minor flaws impacting credibility/validity), "low" (some flaws likely to impact credibility/validity), or "very low" (significant flaws impacting credibility/validity).

Mixed method and case study studies were appraised using Pluye et al.'s (2011) Methods Appraisal Tool (MMAT). Studies were assessed for the employed methods and methodological quality (i.e., qualitative, quantitative randomized control trials or non-randomized control trials, quantitative descriptive, and overall implementation of mixed methods). Each area in MMAT is assessed using "yes," "no," or "can't tell." Studies received a final rating of "high" (no significant flaws), "moderate" (minor flaws impacting credibility/validity), "low" (some flaws likely to impact credibility/validity), or "very low" (significant flaws impacting credibility/validity).

Individual media reports were appraised for their quality using the Authority, Accuracy, Coverage, Objectivity, Date, and Significance (AACODS) (Tyndall, 2008) tool. Each area in AACODS is assessed using "yes," "no," or "can't tell." Studies received a final rating of "high" (no significant flaws), "moderate" (minor flaws impacting credibility/validity), "low" (some flaws likely to impact credibility/validity), or "very low" (significant flaws impacting credibility/validity).

2.8 Extraction of Data from Selected Individual Studies

Study characteristics and key findings along with supporting information were extracted from individual data-based primary studies of all methodological streams. We used the general process of reading and re-reading the full article, especially the abstract, results/ findings/ analysis, and discussion/ conclusion sections to identify the characteristics and findings of interest. The following study characteristics were extracted: method; country focus; disaster/ emergency type; disaster/ emergency phase; and whether at-risk/ vulnerable population. These characteristics were of interest to the WHO. The key findings and supporting information from each study were also extracted. The purpose of extraction of findings was to identify and note evidence of interest that mapped onto the phenomena of interest and the outcomes/ impacts related to the review objective.

Given that only one publication (Johnson & Slovic, 2015)

used comparison groups (randomized or non-randomized) and presence of heterogeneity of studies and outcomes, a quantitative meta-analysis was not suitable for the review. As such, as recommended in Section 11.7.2 of the Cochrane Handbook (Higgins & Green, 2011) dealing with situations where meta-analyses are not possible to conduct, we followed a narrative summary approach (see also Popay et al., 2006) to extraction of findings from studies in all four methodological streams.

As per the narrative summary approach, each finding along with supporting information was extracted in the form of short 3-5 sentence paragraphs. The findings focused on the phenomena of interest broadly and the outcomes/ impacts specifically, and the support for each finding was in the form of quantitative and qualitative information. From quantitative studies, we extracted numerical data, such as means, standard deviations, and probability values. While extracting these data, we kept in mind whether the study was a group comparison (randomized, non-randomized) or descriptive. From qualitative studies, we extracted key phrases, sentences, and direct quotations. From mixed-method and case study studies, we extracted numerical data and key phrases, sentences, and direct quotations as appropriate related to each method. The extraction included page and paragraph numbers for the supporting information as well.

2.9 Quality Assurance of Extraction of Data from Individual Studies

An initial a priori codebook for extracting study characteristics and findings from individual studies was developed based on examples available from the WHO. After receiving feedback on a draft from team members, the WHO methodologist, and the WHO, the document was suitably revised. Next, two pilot tests of the codebook were conducted, one for extracting study characteristics and one for extracting findings and supporting information, using approximately 1% of the English language articles/ reports with three team members. The pilot tests generated suggestions for refinement and the final codebook was created after incorporating this feedback. After this, training sessions for the use of the codebook were conducted with the full research team. Using the codebook, the data extraction from individual studies was done by a team member (English language by the lead author of the review; other UN languages by a native reader) and the output was scrutinized by at least one other team member. The final extracted data reflected corrections based on the team member feedback.

2.10 Synthesis of Findings

2.10.1 General Process

The synthesis of findings was done in two stages as presented in the process design in Figure 1. In the first stage, findings from individual studies were synthesized within methodological streams and then these within-method synthesized findings were evaluated for certainty/ confidence using appropriate tools. In the second stage, the within-method synthesized findings were synthesized across methodological streams, taking into account the certainty/ confidence evaluations.

In both the within-method and across-method stages, the synthesis of findings included subgroup analyses. These included examination of type of emergency event, phase of emergency event, country of emergency event, and presence of vulnerable population. The last two subgroups allowed considerations of equity in the synthesized findings.

The synthesis of findings was done by the lead author of the review. The synthesis process and the synthesized findings were discussed with all team members in weekly meetings. One team member closely read the synthesized findings and offered critique. The synthesized findings were developed and finalized based on the discussion and critique.

2.10.2 Synthesis of Findings Within Each Methodological Stream

For each methodological stream, the synthesized findings were created by building explanatory and higher level analytical statements supported by quantitative and qualitative evidence from individual studies.

For the two quantitative methodological streams, we again took directions from Section 11.7.2 of the Cochrane Handbook (Higgins & Green, 2011) dealing with results without meta-analyses and followed a narrative summary approach to synthesis of findings. For the qualitative methodological stream, we broadly followed the framework synthesis model (Barnett-Page, & Thomas, 2009; Pope, Ziebland, & Mays, 2000). We found this model suited to organize and analyze large amounts of data, which for us was represented by the corpus of findings and supporting evidence. The model is a mix of deductive-inductive

processes. As part of the codebook noted in Section 2.9 above, we started with a list of a priori framework categories generated from review objectives and phenomena of interest concepts, and modified the list as appropriate based on prior subject matter knowledge and reading of individual studies. Our goal was to synthesize the findings by identifying themes that emerged across the findings from individual studies and fit the framework categories. For the mixed-method and case study methodological stream, the individual studies typically did not differentiate their overall findings based on type of methodology. For this stream, thus, we looked at the findings holistically and followed a broadly narrative summary approach.

The assessment of certainty/ confidence of synthesized findings was done separately for each methodological stream using available tools. Quantitative-comparison groups within-method synthesized findings were assessed for certainty using the Grading of Recommendations Assessment, Development, and Evaluation (GRADE) approach (GRADE Working Group, 2004; Guyatt et al., 2011; Higgins & Green, 2011). Findings were assessed on allocation sequence and concealment, baseline outcomes and characteristics, protections against contamination(s), presence of selective outcome reporting, and other possible forms of bias. Each category was given a rating of "low risk" (most information from studies at low risk of bias), "unclear risk" (most information from studies at low or unclear risk of bias", and "high risk" (large proportion of information from studies at high risk of bias) More detailed information on the definitions of levels of risk used in this tool is available in section 12.2.2 of the Cochrane Handbook (Higgins & Green, 2011). Findings received a final rating of "high quality" (it is highly likely that new research will not modify the finding substantially), "moderate quality" (it is somewhat likely that new research will not modify the finding substantially), "low quality" (it is somewhat likely that new research will modify the finding substantially), or "very low quality" (it is highly likely that new research will modify the finding substantially).

Quantitative-descriptive survey within-method synthesized findings were assessed for certainty using a tool developed for the present review that was based on the principles of Grading of Recommendations Assessment, Development, and Evaluation (GRADE) as noted above. Adjustments were made to the GRADE process to create the tool for evaluation of certainty of findings from quantitative cross-sectional surveys that did not have comparison groups for outcomes of interest. There were four evaluation categories: High quality (highly likely that new evidence will *not* substantially modify the study findings); moderate quality (somewhat likely that new evidence will *not* substantially modify the study findings); Low quality (somewhat likely that new evidence will substantially modify the study findings); and very low quality (highly likely that new evidence will substantially modify the study findings). The evaluation categories were based on factors that can reduce the quality of study findings: Limitations in study design or execution; inconsistency of results; indirectness of evidence; imprecision of results; and publication bias for findings collated across multiple quantitative studies.

Qualitative within-method synthesized findings were assessed for confidence using GRADE-Confidence in the Evidence from Reviews of Qualitative research (GRADE-CERQual; Lewin et al., 2015). Findings were assessed on methodological limitations, relevance, coherence, and adequacy of data supporting the finding. Each finding was then given a rating of "high confidence" (it is highly likely that the finding is a representation of the phenomena), "moderate confidence" (it is likely that the finding is a representation of the phenomena "low confidence" (it is possible that the finding is a representation of the phenomena), or "very low confidence" (it was not clear if the finding is a representation of the phenomena).

Mixed method and case study within-method synthesized findings were assessed for certainty/ confidence using principles of GRADE and GRADE-CERQual approaches as appropriate. It should be noted that the adaptation of GRADE principles for application to descriptive quantitative studies and use of GRADE-CERQual principles for application to mixed-method studies has not been approved by the tool originators.

2.10.3 Synthesis of Findings Across Methodological Streams

We synthesized the findings across the four methodological streams to develop an overarching synthesis of findings. The synthesized findings within a methodological stream were compared and contrasted with findings from the other methodological streams. Whenever the findings supported and amplified each other, they were combined into higher order findings that represented synthesis across the method streams. The evaluation of certainty in the within-method synthesized findings was kept in mind during this

process.

All methodological streams did not yield the same kind or similar number of synthesized findings. We did not consider this a problematic issue as we were seeking to find the points of alignment of the findings across the method streams rather than simply merging them together, which would have given some methodological streams more importance than others.

Within-method findings that did not contribute to an across-method higher order finding were analyzed thematically. These thematic analyses were used to uncover a nuance or modification to the across-method findings, which were then either used to create a new higher order across-method finding or incorporated into an existing across-method finding.

A very few synthesized findings within a methodological stream provided evidence that countered the synthesized findings from other methodological streams. Whenever this happened, we strived to retain this finding as a separate finding in the final set of across-method findings or used it to modify an existing across-method finding.

3.0 RESULTS

3.1 Study Selection

For English language literature search, almost 2900 titles and abstracts were scanned, of which about 1700 full-texts were quickly read. After this, 73 full-texts were downloaded, of which the 33 data-based primary studies were selected for data extraction. These details and those for Arabic, Chinese, French, Russian, and Spanish languages are provided in Table 2.[2]

3.2 Study Characteristics

Table 3 provides the study characteristics (country focus, disaster/ emergency type, emergency phase, and vulnerable/ at-risk population groups) as well as method type and relevancy judgments for both English and other UN languages. There were 33 English language studies, of which six were directly relevant, 17 were indirectly relevant, and 10 were partially relevant. Of the 13 other UN languages (i.e., not English) studies, there were no Arabic, one Chinese, five French, three Russian, and four Spanish studies. Seven studies were directly relevant and six were indirectly relevant. The relevancy was judged as only direct and indirect due to lack of sufficient clarity for the partial and unclear categories when applied to non-English languages.

3.3 Quality Appraisal of Individual Studies

Of the 33 English language studies, one was placed in the quantitative-comparison group stream, 10 in the quantitative-descriptive survey stream, 11 in the qualitative stream, and 11 in the mixed methods/ case studies stream. The studies were appraised for their quality as discussed in Section 2.7 above and the appraisals are presented in Table 4. For the other UN languages, a quality appraisal could not be determined for all the studies. This is noted as needed when evaluating the certainty/ confidence of the synthesized findings.[3]

3.4 Synthesis of Findings Within Methodological Stream and Evaluation of Certainty and Confidence

Findings from individual studies, both English and other UN languages, were put into four method streams as dis-

[2] There was no grey literature included in the present review. All the grey literature identified relevant to the review question did not include any data-based primary studies; instead, the literature either was best practices that related the practices to the existing research or it was theoretical essays, that referenced data-based studies and other essays. Similarly, no media reports were included in the review for lack of data-based findings. Two media reports were identified for the review objective in the search for English-language news stories. Both reports were press releases and did not report any data.

[3] The tables for English language studies that present the quality rating, as well as relevancy and extracted findings, for each study can be obtained from the first author.

cussed above and these findings were synthesized within each method. Table 5 provides all details, which include the within-method synthesized findings, citations supporting each synthesized finding, evaluation of certainty/ confidence of the synthesized finding (as described in Section 2.10.2 above), and explanation of this evaluation. As seen from the table, an individual study could support more than one synthesized finding and most synthesized findings were supported by multiple studies though a few had support from only one study.

The quantitative comparison group stream had one synthesized finding. It was supported by a single study that covered an infectious disease event in the United States, with a focus on the onset and containment phases. No vulnerable populations were studied. The evaluation of certainty in the finding ranged from low to moderate.

The quantitative descriptive survey stream had six synthesized findings. Two findings were supported by only a single study whereas the rest were supported by multiple studies. The countries covered included China, India, Mexico, New Zealand, Thailand, the United Kingdom, the United States, and general global. Bioterrorism, cyclone, earthquake, foodborne illness, hurricane, industrial accident, infectious disease, volcanic, and wildfire events were covered. All four phases of an event were covered, with emphasis on preparation. Vulnerable populations were covered in two findings. The evaluation of certainty in the findings included high (1 finding), moderate (2 findings), and low (3 findings).

The qualitative stream had six synthesized findings. One finding was supported by only a single study whereas the rest were supported by multiple studies. The countries covered included Australia, Canada, China, general European Union countries, France, Iran, Japan, Russia, the United Kingdom, and the United States. Bioterrorism, earthquake, flood, hurricane, infectious disease, tornado, and general public health events were covered. All four phases were covered, with emphasis on preparation and onset, along with evaluation. Vulnerable populations were covered in three findings. The evaluation of confidence in the findings were high (1 finding) and moderate (5 findings).

The mixed methods/ case study stream had eight synthesized findings. Two findings were supported by only a single study whereas the rest were supported by multiple studies. The countries covered included Canada, Chile, general European Union countries, Finland, France, Indonesia, Israel, New Zealand, Russia, Singapore, South Africa, and the United States. Air pollution, earthquake, flood, foodborne illness, industrial accident, infectious disease, landslide, and general public health events were covered. All four phases of an event were covered, with emphasis on preparation, along with evaluation. Vulnerable populations were covered in one of the findings. The evaluation of certainty/ confidence in the findings was high (1 finding) and moderate (7 findings).

3.5 Synthesis of Findings Across Methodological Streams

The across-method findings were the synthesis of the findings within the four method streams. Table 6 presents the details, which include the across-method synthesized findings, citations supporting a finding, and the evaluation of certainty/ confidence of the finding (as described in Section 2.10.2 above).

There were total nine synthesized findings across the four method streams. Of these, one synthesized finding was based on all four methods, three synthesized findings were based on three methods, two synthesized findings were based on two methods, and two synthesized findings were based on just one method. The across-method synthesis sought to identify commonalities in themes across the method streams but at the same time it allowed for findings that were unique to not get subsumed under more general themes; this resulted in two synthesized findings that drew only from one method.

The quantitative comparison group within-method synthesized finding appeared in one across-method synthesized finding, quantitative descriptive survey within-method synthesized findings appeared in three across-method findings, qualitative within-method synthesized findings appeared in three across-method synthesized findings, and mixed method/ case study within-method synthesized findings appeared in four across-method findings.

The certainty/ confidence of each final across-method synthesized finding was an aggregation of the method-specific certainty/ confidence assessments of the within-method findings that constituted it. The range of the aggregated certainty/ confidence was moderate-to-high for two findings, moderate for three findings, low-to-high for three findings, and low-to-moderate for one finding. Although, no overall single certainty/ confidence judgment was created

for a final synthesized finding, based on the range of assessments, a judgment of moderate certainty/ confidence can be reasonably assigned to each finding and as such to the findings as a whole set.

3.5.1 Core Aspects of Across-Method Synthesized Findings

The review sought to answer the question, What are the best ways to communicate uncertainties to public audiences, vulnerable communities, and stakeholders? The review took the question more broadly and studied it as the phenomenon of uncertainty in the context of public health emergency events. Each of the nine final synthesized findings covered several features of the phenomenon and the core aspects of each of finding are presented next, broadly organized around the research question.

1. For the public, uncertainty related to a public health emergency event is in terms of uncertainty information conveyed in messages as well as uncertainty experienced. The uncertainty information can be directly (or, objectively) in the form of numerical probabilities ("60% chance"), linguistic likelihoods ("strong chance"), and absence ("no information") or indirectly (or, subjectively) in the form of incomplete, inconsistent, and conflicting/ contradictory information, which all can lead to a cognitive and affective experience of uncertainty. Additionally, there are several types/ sources of uncertainty, such as uncertainty regarding personal and others' safety, event knowledge, influx of non-local people, and future of village/ town, which change across the time course of the phases of an event. Uncertainty is separate from values issues, which deal with judging the appropriate standards of public protection (Afifi, W., Afifi, T., & Merrill, 2014; Afifi, W., Felix, &, Afifi, T., 2012; Alipour et al., 2015; Downton, Morss, Wilhelm, Gruntfest, & Higgins, 2005; Doyle, Johnston, McClure, & Paton, 2011; Duchêne, & Journel, 2004 [French]; Janmaimool, & Watanbe, 2014; Miles, & Frewer, 2003; Podkorytov (2014) [Russian]).

2. The public's experience of uncertainty in a public health emergency event is due to lack of information and to reduce this uncertainty it actively seeks both general and specific information from traditional mass media, social media, and interpersonal network sources (family, doctors, nurses, community leaders) during the course of an event. The uncertainty experienced by the public is associated with other predictors as well, including lack of: disaster management coordination and cooperation at the local level; disaster management plan that is interactive with the public; integrated management of official response to event across all mass and social media and other domains; and speedy, regular, timely, reliable, and detailed information about event progression. Individual difference factors such as perceptions of risk also are associated with experience of uncertainty (Acar, & Muraki, 2011; Afifi, W., Afifi, T., & Merrill, 2014; Afifi, W., Felix, &, Afifi, T., 2012; Aldunce, & León, 2007; Barengo, Tuomilehto, Nissinen, & Puska, 2011 [Spanish]; Bird, Ling, & Haynes, 2012; Burke, & Zhou, 2009; Dabner, 2012; Francescutti, 2007 [Spanish]; Karan, Aileen, & Elaine, 2007; Muniz, 2011 [Spanish]; Skinner, & Rampersad, 2014; Spence, Lachlan, & Burke, 2007; Taylor-Robinson, Elders, Milton, & Thurston, 2009; Vallejos-Romero, & Onate Nancucheo, 2013 [Spanish])

3. The public should receive explicit information about uncertainties associated with public health emergency events in the communications sent by authorities. There is universal agreement among experts and researchers regarding this, although a few experts/ scientists indicate that disseminating scientific uncertainty to a public unable to conceptualize uncertainty in scientific terms can have a negative impact on the public's trust of science, scientists, and scientific institutions, and can lead to panic and confusion regarding the extent and impact of a particular event (Doyle, Johnston, McClure, & Paton, 2011; Frewer et al., 2003; Holmes, Henrich, Hancock, & Lestou, 2009; Janmaimool, & Watanbe, 2014; Li, Qian, Ma, & Ge, 2010 [Chinese]; Masse, Weinstock, Dessy, & Moisan, 2011 [French]; Pappenberger et al., 2013; Quinn, Thomas, & Kumar, 2008; Taylor-Clark, Koh, & Viswanath, 2007; UN/FAO, 2011[French]).

4. For the general public, uncertainty information in messages provided by authorities at times of public health emergency events is uniformly associated with desirable outcomes such as reduced uncertainty about health protection actions; reduced reliance on misinformation, rumors, and sensationalized media stories; and improved response to future warnings. However, when openly acknowledging uncertainties the possibility of some undesirable outcomes for some vulnerable populations needs to be kept in mind, such as reduction in trust in authorities and vacillation about evacuation (Duchêne, & Journel, 2004 [French]; Gryzunova, 2012 [Russian]; Jakubowski, & Charpak, 2004 [French]; Janmaimool, & Watanbe, 2014; Johnson & Slovic, 2015; Lord, 2009 [French]; McClure, Doyle, & Velluppillai,

2015; Miles, & Frewer, 2003; Morss & Hayden, 2010; Pozdnyakov, 2011 [Russian]; Ramos, Mathevet, Thielen, & Pappenberger, 2010; Sharma, & Patt, 2012; Skinner, & Rampersad, 2014; Vaughan, Tinker, Truman, Edelson, & Morse, 2012).

5. For vulnerable communities, the development of messages containing uncertainty information about public health emergency events must keep in mind the whole living environment of the intended audience. People's lives can be full of uncertainties due to poverty and not just because of a particular hazard or event. It should be recognized that issues of economic development and environment are just as central to reducing uncertainty regarding an event as messages from authorities (Aldunce, & León, 2007; van Voorst, 2015).

6. The public's understanding of some uncertainty information associated with public health emergency event likelihood estimates is error prone and this error is true of various stakeholders such as experts (scientists, non-scientists) as well. For both, the likelihood of event occurrence is not understood as being uniform throughout a time window. Additionally for experts, translation of verbal descriptions of event likelihood uncertainty to numerical terms is not fully accurate (Doyle, Johnston, McClure, & Paton, 2011; Doyle, McClure, Johnston, & Paton, 2014; McClure, Doyle, & Velluppillai, 2015).

7. Uncertainty of data and knowledge about public health emergency events influences interactions within and among various stakeholders such as groups of experts and between experts and policy/ decision makers, which in turn affects the decision-making process in complex ways. A final decision to be communicated to the public (e.g., evacuation warning) can be seen as the end point of a chain of decisions that includes a flow of uncertainty information where different experts and policy makers in the decision chain understand uncertainty differently and tend to act in face of uncertain information differently. Additionally, uncertain scientific knowledge is entwined with values issues (appropriate standards for public protection), which makes the decision chain process even more complex (Downton et al., 2005; Morss, 2010; Morss, Demuth, Bostrom, Lazo, & Lazrus, 2015; Ramos, Mathevet, Thielen, & Pappenberger, 2010).

8. The media are an important stakeholder and if their coverage of a public health emergency event emphasizes rapidly changing, contradictory, and conflicting information, especially that differs from official information from authorities, this can increase uncertainty in the public, which in turn can lead to several undesirable outcomes in the public such as lack of trust in authorities and recommended actions; confusion and fear; reduced intentions for health protective behaviors; and reduced attention to health risk news. Such media coverage also puts a constraint on the ability of other stakeholders such as frontline health/medical workers to address the public's uncertainty about effective response to the event (Afifi, W., Afifi, T., & Merrill, 2014; Quinn, Thomas, & Kumar, 2008; Rousseau et al., 2008; Taylor-Clark et al., 2007).

9. Various stakeholders such as medical/ health care workers and policy makers experience uncertainty about a public health emergency event. Consequently, the decision making regarding communication to the public about the event becomes uncertain, when the official information about the event is absent or contradictory/ inconsistent. In addition, when authorities rush to declare a "fact" about an emergent event without transparently acknowledging uncertainties, it can lead to compromised decision making by relevant stakeholders (Gesser-Edelsburg, Mordini, James, Greco, & Green, 2014; Rousseau et al., 2008).

3.5.2 Country, Event, Phase, and Vulnerable Population Coverage

As seen from Table 6, the countries covered in the across-method synthesized findings showed mostly high and middle-income countries in Asia, Europe, North America, and Oceania. Only one country was covered in Africa and two countries in Central and South America.

The event most covered in the findings was infectious disease, in both English language and other UN languages studies. Other relatively common events included flood and earthquake. All four event phases were covered though there was heavy emphasis on the preparation phase, followed by onset and containment phases; relatively there was much less coverage of the recovery phase and evaluation.

The findings included only seven studies (four English language [Taylor-Clark, Koh, & Viswanath, 2007; Taylor-Robinson, Elders, Milton, & Thurston, 2009; Vaughan et al., 2012; van Voorst, 2015] and three other UN languages [Jakubowski & Charpak, 2004; Masse, Weinstock, Dessy, & Moisan, 2011; UN/FAO 2011]) that explicitly examined at-risk/ vulnerable populations. Thus, the coverage of such populations was minimal.

4.0 DISCUSSION

The synthesis of evidence on the phenomenon of uncertainty during public health emergency events was based on findings from 46 studies (33 English language, 13 other UN languages). The individual studies were appraised for quality after which findings were extracted from each study and placed within four methodological streams. Next, the individual-study findings within each methodological stream were synthesized and these findings were evaluated for certainty/ confidence. Lastly, the within-method synthesized findings were further synthesized across the four methods to yield a final set of across-method synthesized findings. The certainty/ confidence of the final set of synthesized findings was judged as moderate (as opposed to high or low) based on the aggregated range of method specific assessment tool-derived certainty/ confidence appraisals of the within-method synthesized findings.

4.1 Findings from Present Review Vis-a-Vis Findings from Existing Reviews

There were four existing reviews assessed as high and moderate quality whose findings were relevant to the present review (Bradley, McFarland, & Clarke, 2014; Gesser-Edelsburg et al., 2015; Meredith et al., 2008; Visschers, Meertens, Passchier, & de Vries, 2009).[4] A review (Liu, Bartz, & Duke, 2016) was published after the completion of the project is included here but was not assessed for quality. The results from the present review generally overlap with and extend these findings and provide new findings as well.

The present findings broadly replicate and extend the previous findings about the conceptualization of uncertainty and identification of its different aspects. Similar to the previous findings, the present review did not find a definitive view of uncertainty in the literature. Although there are several conceptualizations of uncertainty, there seems to be no consensus on the best view for a public health emergency event. Likewise, although several types and sources of uncertainty are noted in the present results, there is no clear agreement on a list that would be the most applicable to the public health emergency event situation. Along the same lines, the present review also notes that the research literature remains generally atheoretical. Additionally, the present findings also show that the format for presenting the likelihood information for occurrence of events in messages influences how the information is understood.

At least three new findings are highlighted in the present review. First, the present findings firmly distinguish between uncertainty as experience and uncertainty as information. Although the two concepts are related -- uncertainty information can decrease/ increase experience of uncertainty and uncertainty experience can modulate how uncertainty information is interpreted -- the findings show that these are clearly two separate concepts. Both concepts are essential to fully understand the nature of uncertainty in public health emergency events. Second, are the findings related to experts' decision-making under conditions of uncertainty regarding data and knowledge that they have and how this uncertainty gets propagated through the chain of decisions that lead to a public forecast or warning announcement. Third, are the findings related to the role of absent, contradictory, and inconsistent information in the mass media, which can increase uncertainty in both the public and medical/ health workers as well as negatively influence the decision-making in organizations and impede their efforts.

4.2 Suggestions for Practice

The final set of findings provides an understanding of the phenomenon of uncertainty in the situation of public health emergency events and the message and activities that can be undertaken by authorities to communicate and reduce uncertainty in this context. Overall, the findings lend them-

[4] An existing review (Vaughan and Tinker, 2008) was rated as low quality and it was "unpacked" for its data-based primary studies, which were added to the literature for the present review. The quality of the existing reviews was rated using a modified Assessment of Multiple Systematic Reviews (AMSTAR) quality appraisal checklist (Shea et al., 2007). AMSTAR consists of 11 elements that address the reviews' design (i.e., a priori), data extraction, details of the literature search, inclusion of grey literature, characteristics, methods, and scientific quality of included studies, publication bias, and acknowledgement of conflict of interest(s). Each area in AMSTAR is assessed using "yes," "no", "can't answer," or "not applicable." Studies received a final rating of "high" (no significant flaws), "moderate" (minor flaws impacting credibility/validity), or "low" (some flaws likely to impact credibility/ validity). Two coders did the coding independently with high agreement. The final quality assessment was judged after the coders resolved any differences.

selves to at least four suggestions for authorities when designing messages for addressing uncertainty related to public health emergency events.

First, authorities should keep in mind that uncertainty is both a lived experience and a characteristic of information, and in both senses is multifaceted with multiple types and sources (e.g., Afifi, W., Felix, & Afifi, T., 2012; Alipour et al., 2015). This means that authorities need to design messages with a high level of specificity of uncertainty type and source, where the magnitude of uncertainty may vary considerably across the types and sources as well as across the phases of an event. This also means that before and while designing messages, authorities need to monitor the public's experience of uncertainty due to the actual emergency event and the public's response to uncertainty information in messages about the event as these constitute two different, though overlapping, aspects that together determine decision-making and behavioral response.

Second, there is general agreement among experts and researchers, though with some caveats, that communication by authorities to the public should include explicit information about uncertainties associated with events (e.g., Aldunce & Leon, 2007; Frewer et al., 2003; Karan, Aileen, & Elaine, 2007). It is important to ensure that the information provided is consistent and not contradictory, and is presented clearly and in an easy to understand manner. Messages conveying uncertainty information that disregard this will fail to work.

Third, authorities should be sensitive to that all vulnerable groups may not process uncertainty information the same way (e.g., Vaughan et al., 2012). The findings note, for example, the processing and effects differences between urban African American and Hispanic minorities in the United States with regards to uncertainty information in messages. In this regard, authorities should also be cognizant of the fact that the life circumstances of vulnerable groups, such as people from low socioeconomic backgrounds, might have a myriad of uncertainties stemming from poverty, chronic illness, among other factors (e.g., van Voorst, 2015). As such, the uncertainty associated with a public health emergency event might be just one source of uncertainty among many others.

Fourth, authorities should remain keenly aware that experts' (both scientists and non-scientists) and policy makers' handling of uncertainty information in forecasting, warning, and other similar decision-making is a complex process that may be similar to the general public's processing of uncertainty information (e.g., Downton et al., 2005; Gesser-Edelsburg et al., 2014)). Along the same lines, how media professionals as well as health and rescue workers experience uncertainty and process information about it may not be too different from the public's (e.g., Rousseau et al., 2008). As such, authorities must not solely focus on communicating uncertainty information to the public but also keep in mind the need for addressing uncertainty for various other stakeholders.

Authorities should carefully consider at least these four aspects of uncertainty in the context of public health emergency events when developing the best ways to communicate uncertainties to the general public, at-risk/ vulnerable populations, and stakeholders.

4.3 Research Gaps in the Reviewed Literature

The present review identified seven main gaps in the reviewed literature on the phenomenon of uncertainty during public health emergency events. These gaps suggest avenues for further research. First, there should be a comprehensive examination of the various conceptualizations and sources of uncertainty, separately as well as jointly for uncertainty experience and uncertainty information. There are studies that investigated different sets of sources, but the review did not identify any study that comprehensively examined all relevant concepts and sources, and tested their relationships with outcome and predictor variables of interest.

Second, there is a paucity of studies examining message designs such as linguistic choices and visual formats that can augment understanding of uncertainty information. There do exist studies that have investigated this, but the vast majority have been conducted with college students in laboratories. Such studies in the future need to be conducted in the field with populations affected or likely to be affected by public health emergency events.

Third, there is insufficient comparative research across countries, especially across low and high income countries. To fully understand how the characteristics of low income countries, especially in terms of infrastructure, history, and political climate, might influence uncertainty processes differently relative to high income countries, there needs to be comparison of such countries. If practices of health authorities need to be different across low and high income coun-

tries, specific factors and relationships among the factors that contribute to uncertainty processes should be compared across countries.

Fourth, there is not enough attention paid to the most vulnerable and disadvantaged populations. These are often the populations who have the least access to information resources and exposure to official information before, during, and after an event, and as such face the most uncertainty. Uncertainty is alleviated through information and when there is insufficient access to traditional and new media sources, information may be predominantly sought from interpersonal networks. There are not enough studies that investigate information seeking processes in such media access-poor populations.

Fifth, completely absent in the literature are longitudinal studies. It is not always necessary to have randomized comparison group research design, which may be precluded due to the nature of public health emergency events, to draw out causal relationships. Such linkages between variables of interest, such as health protection behavior as an outcome of uncertainty information in a message, can also be examined using a longitudinal research design where data of interest are measured at multiple time points. Such a research design can better reveal how uncertainty dynamically varies during the phases of an event; even if say, preparation and recovery phases are only used for data collection, this will still provide insight into how uncertainty information affects different variables across the phases. Such a design can also provide knowledge about how uncertainty experience varies and how it interacts with uncertainty information through the course of an event.

Sixth, there is insufficient research on how uncertainty information is determined and processed by experts and then disseminated to their colleagues within and across organizations and then to the public. Although some research exists, it has not been conducted for decision-making processes in a wide variety of public health emergency events, organizations, and scientific/ technical areas and disciplines. It is commonly assumed that all experts in all domains accurately understand and in turn correctly disseminate uncertainty information. The sample of studies addressing this topic in the present review, though small in number, suggests otherwise.

Seventh, theories of communication research that directly speak to uncertainty have not been used to investigate this phenomenon in the context of public health emergency events. There are at least three theories, as discussed by Bradac (2001), that can substantially enhance the understanding of uncertainty experience and processing of uncertainty information. *Uncertainty reduction theory* (Berger & Calabrese, 1975) proposes that uncertainty experience is an aversive mental state that motivates seeking of information to reduce the uncertainty. In contrast, *uncertainty management theory* (Babrow, Hines, & Kasch, 2000; Brashers, 2001) posits that uncertainty experience is not necessarily a negative mental state that requires reduction, but can be experienced as positive or neutral as well such that it may motivate information seeking to increase rather than reduce uncertainty. Extending this view that uncertainty experience may be both negative and positive, *problematic integration theory* (Babrow, 2001; Brashers, 2001) posits that uncertainty is linked to assessments of probability of an outcome and favorability of the outcome, and their integration with one another and with existing knowledge and beliefs. Public health emergency communication research focuses on the processing of probability aspects of uncertainty information. Future research should also investigate the perception of favorability of uncertainty information to see its role in the experience of uncertainty during public health emergency events. The conditions of threat that constitute such events are likely to result in an experience of uncertainty that is aversive along with a desire to reduce this state; however, the last two theories above imply that this assumption may not perhaps hold true for all populations, all phases of an event, or all types of uncertainty information. Future research should measure uncertainty experience in both its negative and positive forms (see Morss & Hayden, 2010 in this regard) to see how the degree of this aversive state might influence the type and amount of information that is sought from authorities during public health emergency events.

4.4 Implications for Theory

The present review showed a general absence of testing and development of theories and models. To develop effective strategies for addressing uncertainty during public health emergency events, integrative models and theoretical frameworks that rest on empirical findings can increase the likelihood of accurate predictions, which can assist with planning and management of such events. Based on the final set of findings from the present review, we offer three propositions that can contribute to theoretical frameworks for understand-

ing uncertainty in the context of public health emergency events.

First, a distinction between uncertainty experience and uncertainty information is required. The two concepts are intertwined and to fully understand the nature of uncertainty, it is not advisable to investigate one without the other. The two concepts, their various sources, and the relationships among them quite likely behave similarly, if not identically, in the general public and in communities of experts, policy makers, health and rescue workers and officials, and other related stakeholders. That is, it is quite likely that uncertainty is experienced in the same general ways by the public and other stakeholders, and uncertainty information is understood and misunderstood by the general public and other stakeholders alike.

Second, the experience of uncertainty may be a defining feature of a public health emergency event not only for the public and experts, policy makers, and related stakeholders, but for journalists and other media professionals as well. The mandate of media professionals is to report all relevant information to the public in a timely manner, including information that might be contradictory/ inconsistent, which will be perceived as uncertain. This media information is received by and influences the public as well as frontline medical/ health workers and other related stakeholders who access the media during public health emergency events.

Third, given the first two propositions, perhaps cautiously, a theoretical proposition in the form of a metaphor of a cascade of uncertainty propagation can be forwarded. The propagation of uncertainty, both experience and information, can be seen as having multiple origination points in experts, public, policy makers, media professionals, frontline medical/health officials and workers, and other stakeholders as soon as they detect, specify, or experience a public health emergency event and begin disseminating uncertainty information about the event. The uncertainty cascade does not only include the decision to disseminate a forecast or warning message by the authorities but it also includes the decisions the public, media, and other stakeholders make after processing uncertainty information under experienced uncertainty. The uncertainty cascade travels from multiple points to multiple points (e.g., from media to public, from media to frontline health workers, from public to policy makers, from policy makers to media) in a reciprocal exchange as organizations, authorities, public, and other stakeholders make new decisions in response to the decisions made by others. This system-level view of uncertainty in public health emergency events might assist authorities in constructing messages that communicate uncertainty with greater specificity and nuance in relation to the unique circumstances of the different intended audiences and also plan for how unintended audiences might be affected by the same information.

None of the theories and models commonly used to study public health emergency events directly focus on uncertainty. The final set of findings and above propositions can deepen the contributions of existing theories by suggesting pathways for explicitly incorporating uncertainty in their formulations.

Sheppard, Janoske, and Liu (2012; see Figure on p. 3) provide an overview of a wide range of theories and models, both at the individual-psychological and organizational levels, that have been used in or have relevance to the study of public health emergency events. None of the theories and models have uncertainty as a prominent variable, and so they can include uncertainty experience and uncertainty information as distinct but interconnected variables. The theories and models typically investigate the general public; they can be extended to studying risk perceptions and processing in experts, policy makers, health/medical staff, and related stakeholders as well as media professionals. These same suggestions can also be made for the various individual-level psychological models that examine risk perceptions (for an overview see Covello, Peters, Wojtecki, & Hyde, 2001; see also Glik, 2007). These models explain how risk information is processed, how risk perceptions are formed, and how risk decisions are made, which all can be informed by giving uncertainty a salient role and studied in populations other than the general public.

Chaos theory (Seeger, 2002; Sellnow, Seeger, &Ulmer, 2002) and dynamic systems (Burns & Slovic, 2007) perspectives on public health emergency events are in most concordance with the cascade of uncertainty propagation proposition suggested above. The perspectives seek to advance understanding of public health emergency events by viewing then as systems that are nonlinear, complex, and unpredictable. These perspectives can easily incorporate in their theorizing and computer modeling how uncertainty experience and uncertainty information diffuses through the public and various stakeholders that together constitute a community.

4.5 Limitations of the Present Review

The present systematic review has two main limitations. First, the non-English UN languages articles and reports were only selectively, and not fully, translated into English, which may have led to some information to be missed during data extraction. Second, the data extraction from individual studies was done principally by one person (English language by the lead author of the review; other UN languages by a native reader) as was also the case for the synthesis of findings across studies (by the lead author of the review), with the results vetted by at least one other member of the research team. However, this cross-checking process was not formalized, which prevented the statistical calculation of inter-coder reliability to determine the degree of consistency of results.

4.6 Conclusion

Uncertainty experience and communication related to it is a complex phenomenon that is inherent to a public health emergency event. The final set of synthesized findings from the present systematic review deepen our understanding of the phenomenon relative to previous reviews and lead to suggestions for practice, future research, and a theoretical proposition that can guide development of a conceptual model. As a whole, these can assist various stakeholders with managing uncertainty experience and disseminating uncertainty information to reduce negative health outcomes and enhance recovery efforts.

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Table 1. *Search Terms* (back to text)

Main Search Term	Boolean 'And' Term (Used With Any of the Main Search Terms)
Disaster*	At risk population; at risk community
Disaster plan*	At risk
Communication	Uncertaint*
Risk communication	Warning
Emergenc*	Community participation
Hazard*	Stakeholder
Risk*	Social network communit*
Threat*	Public; audience
Emergency preparedness	Duty to protect
Emergency management	Safety
Crisis communication	Risk population; risk community
Cris!s (or other truncation for a specific database, e.g. ?, #)	
Disaster preparedness	Community
Hazard communication	Social media
Emergency communication	Facebook
Catastrophe communication	Twitter
Health communication	New media

Table 2. *Study Selection* (back to text)

Language	Total Number of Titles and Abstracts Scanned	Total Number of Full-Texts Quickly Scanned	Total Number of Full-Texts Downloaded	Total Number of Full-Texts Fully Read	Total Number of Full-Texts Selected for Data Extraction (Only Data-Based Primary Studies)
English	2909	1706	73	73	33
Arabic	6720	---	57	0	0
Chinese	800	---	125	2	1
French	196	---	78	5	5
Russian	870	---	639	3	3
Spanish	No accurate data	---	No accurate data	6	4

Table 3. *Characteristics of Studies* (back to text)

Relevancy	Method General	Country Focus	Disaster/ Emergency Type	Emergency Phase	At-risk Groups
			English Language (33 Studies)		
Direct: 6	QN-CG: 1	Australia: 1	General: 1	All Phases: 5	Yes: 4
Indirect: 17	QN-DS: 10	Canada: 2	Bioterrorism: 2	Preparation: 16	[Low socio-economic status (SES): 2,
Partial: 10	QL: 11	Chile: 1	Cyclones/ Hurricanes: 3	Onset: 7	Minorities: 2,
Unclear: 0	MM, CS: 11	China: 1	Earthquake: 5	Containment: 5	School Children: 1]
		Europe general: 2	Flood: 7	Recovery: 4	
		France: 1	Food Contamination: 2	Evaluation: 1	
		India: 1	Industrial Accident: 2		
		Indonesia: 1	Infectious Disease: 6		
		Iran: 1	Landslides: 1		
		Israel: 1	Tornado: 1		
		Japan: 1	Volcanic: 2		
		New Zealand: 1	Wildfire: 1		
		Singapore: 1			
		South Africa: 1			
		Thailand: 1			
		United Kingdom: 2			
		United States: 12			
			Other UN Languages (13 Studies)		
Direct: 7	QN-CS: 0	Austria: 1	General: 4	Preparation: 2	Yes: 3
Indirect: 6	QN-DS: 2	Belgium: 1	Chemical/Air Pollution: 1	Onset: 1	[Children: 2
	QL: 4	Canada: 3	Flooding: 1	Containment: 1	Chronic Disease: 1
	MM, CS: 7	Chile: 1	Food Safety: 1	Evaluation: 2	Low-SES: 1

China: 1	Infectious Diseases: 6	Preparation, & Containment: 1	Minorities: 1
Finland: 1		Preparation, & Evaluation: 1	Older People: 1
France: 1		Preparation, Onset, & Containment: 1	Pregnant Women: 1]
Mexico: 1		Preparation, Onset, & Recovery: 1	
Norway: 1		Preparation, Onset, & Evaluation: 1	
Russia: 3		Onset, Containment, & Evaluation: 1	
Spain: 1			
United Kingdom: 1			
General: 1			

Notes. (back to text)

Some categories are not mutually exclusive and so the frequencies will not sum to the total of 33 (English language) and 13 (Other UN languages).

Method: Quantitative-Comparison Groups (QN-CG); Quantitative-Descriptive Survey (QN-DS); Qualitative (QL); Mixed-Method/Case Study (MM, CS)

Table 4. *Quality Appraisal of English Language Individual Data-based Primary Studies* (back to text)

Method	Citations (first author only, unless noted otherwise)	Quality Appraisal Rating
QN-CG	Johnson (2015)	Moderate
QN-DS	Afifi (2012); Sharma (2012); Spence (2007); Vaughan (2012)	Moderate
QN-DS	Burke (2009); Doyle (2011); Doyle (2014); Janmaimool (2014); McClure (2015); Miles (2003)	Weak
QL	Alipour (2015); Morss (2015); Taylor-Clark (2007)	High
QL	Acar (2011); Afifi (2014); Bird (2012); Holmes (2009); Morss & Hayden (2010); Pappenberger (2013); Quinn (2008); Taylor-Robinson (2009)	Moderate
MM, CS	Dabner (2012); Downton (2005); Frewer (2003); Karan (2007); Morss (2010); Ramos (2010)	High
MM, CS	Aldunce (2007); Gesser-Edelsburg (2014); Rousseau (2008); van Voorst (2015)	Moderate
MM, CS	Skinner (2014)	Low

Notes.

Method: Quantitative-Comparison Groups (QN-CG); Quantitative-Descriptive Survey (QN-DS); Qualitative (QL); Mixed-Method/ Case Study (MM, CS)

Quality: QN-CG – High, Moderate, Low, Very low; QN-DS – Strong, Moderate, Weak; QL – High, Moderate, Low, Very low; MM, CS – High, Moderate, Low, Very low.

Table 5. *Synthesis of Findings Within Methodological Stream and Evaluation of Certainty/ Confidence* (back to text)

Method	Synthesized Finding Statement (with subgroup analysis of type, phase, and country of disaster, and vulnerable population)	Citations (first author only, unless noted otherwise) Supporting Synthesized Finding Within Method Stream	Evaluation of Certainty/ Confidence of Synthesized Finding Within Method Streams	Explanation of Evaluation
QN-CG	In the United States for an infectious disease event for onset and containment phases, trust in authorities may show a slight decrease as a result of openly acknowledging uncertainties in messages. However, this decrease is only for a small proportion of the total number of message recipients; for the vast majority of message recipients, there is no change in their level of trust.	Johnson (2015)	Low to Moderate	Two studies reported in article, one not a randomized group comparison. Some evaluation categories not applicable or 'cannot tell'.
QN-DS	In Thailand, New Zealand, the United Kingdom, and the United States, for food contamination, industrial accident, volcanic, and wildfire events, and for preparation and recovery phases, it should be noted that there are different types/components to the public's experience of uncertainty. As examples, one classification notes three types: uncertainty regarding personal safety; safety of home; and safety of close others. Another classification also notes three types: uncertainty about event knowledge; data; and outcome. Along the same lines, there is risk assessment uncertainty and event outcome uncertainty. Another classification shows seven types of uncertainty: uncertainty about who is affected; temporal uncertainty (uncertainty about past and future states); measurement uncertainty; uncertainty due to scientific disagreement; uncertainty about the risk to humans; uncertainty about the extent (or size) of the risk; and uncertainty about how to deal with and reduce the risk.	Afifi (2012); Janmaimool (2014); Doyle (2011); Miles (2003)	Low	Not fully overlapping findings by 4 studies, individually appraised as moderate (1) and weak (3).

QN-DS	In China, Mexico, and the United States, for earthquake, hurricane, infectious disease, and wildfire events, and for all phases, the public's experience of uncertainty was due to lack of information and uncertainty was reduced by greater information, and the public actively sought out information to reduce its uncertainty. Uncertainty in a time of crisis can motivate individuals to engage in information seeking, which can alleviate the uncertainty. People seek both general and specific information, and there here are demographic and mass medium differences in information seeking. People seek information (and coping support) from personal networks as well to reduce uncertainty and its impact on mental health.	Afifi (2012); Burke (2009); Spence (2007); Muniz (2011) SP	High	Overlapping findings by 4 studies, individually appraised as strong (1), moderate (2), and weak (1).
QN-DS	In Thailand, New Zealand, and globally, for foodborne illness, industrial accident, and volcanic events, for preparation and containment phases, and including for low SES population, there is general agreement among experts, both scientists and non-scientists, and researchers that communication by authorities to the public should include explicit information about uncertainties associated with events.	Doyle (2011); Janmaimool (2014); FAO/WHO (2011) FR	Moderate	Overlapping findings by 3 studies, individually appraised as moderate (1) and weak (2).
QN-DS	In India, Thailand, New Zealand, the United Kingdom, and the United States, for bioterrorism, cyclone, earthquake, food contamination, and industrial accident events, for preparation, onset, and containment phases, and including for urban minority African American and Hispanic populations, knowledge and understanding of uncertainty information provided in messages as predictor is associated with outcomes of: trust and confidence in authorities; perception of transparency of authorities; experience of fear; response to warnings; likelihood of preparation; and risk perceptions.	Janmaimool (2014); Sharma (2012); McClure (2015); Miles (2003); Vaughan (2012)	Moderate	Overlapping findings by 5 studies, individually appraised as moderate (2) and weak (3).

QN-DS	In New Zealand, for earthquake event, and for preparation phase, the public's understanding of uncertainty information provided in messages was error prone. People rated the likelihood of event occurrence higher in later intervals than in earlier intervals of a time window. This pattern was observed despite the fact that the verbal descriptions of the likelihood of event occurrence in a specific time window did not imply that the event likelihood changed across different intervals of the time window.	McClure (2015)	Low	Finding based on one study, appraised as weak.
QN-DS	In New Zealand, for volcanic events, and for preparation phase, experts' (both scientists, non-scientists) understanding of uncertainty information provided in messages was error prone. Experts rated the likelihood of event occurrence higher in later intervals than in earlier intervals of a time window. Experts did not view the likelihood of a volcanic eruption as being uniform throughout a time window; they instead viewed the likelihood of an event in an earlier time interval as being lower and in a later time interval as being higher as opposed to uniform across all periods in the time window. Similarly, attempts to accurately translate verbal descriptions of event likelihoods/ uncertainty to numerical terms were with problems.	Doyle (2011); Doyle (2014)	Low	Finding based on two studies, both appraised as weak.
QL	In France, Iran, and the United States, for earthquake, flood, and tornado events, for preparation and recovery phases as well as for evaluation, there are different types/ components to the public's experience of uncertainty. Experience of uncertainty is related to: disruption of roles and responsibilities; employment; influx of non-local population; reconstruction without considering of local culture; and not understanding the causes of an event. Experience of uncertainty changes across the time course of an event that includes uncertainty regarding: impact of event; future of schools and village/ town; and decisions about rebuilding.	Afifi (2014); Alipour (2015); Duchêne (2004) FR	Moderate	Overlapping findings by 3 studies, individually appraised as high (1), moderate (1), and low (1)

QL	In Australia, Japan, the United Kingdom, and the United States, for earthquake, flood, tornado, and infectious disease, for all phases, and including for school children, lack of information increases experience of uncertainty and information from authorities reduces this uncertainty. Authorities must provide information speedily, timely, and reliably. People actively seek information to reduce their uncertainty, especially through social media, and the authorities too should use this medium for information dissemination.	Acar (2011); Afifi (2014); Bird (2012); Taylor-Robinson (2009)	High	Overlapping findings by 4 studies, all individually appraised as moderate.
QL	In the United States, for bioterrorism, general public health, and tornado events, for all four phases, and including for low SES minorities population, contradictory and inconsistent information in the media may be seen as uncertain information, which leads to several outcomes including: experience of uncertainty; lack of trust in authorities and recommended actions; confusion and fear; reduced intentions for health protective behaviors such as vaccination; and reduced attention to health risk news.	Afifi (2014); Quinn (2008); Taylor-Clark (2007)	Moderate	Overlapping findings by 3 studies, individually appraised as high (1) and moderate (2).
QL	In Canada, China, several European countries, and the United States, for bioterrorism, flood, general public health, and infectious disease, for preparation, onset, and containment phases as well as evaluation, and including for low SES minorities, pregnant women, children, and people with chronic disease populations, there is general agreement among experts and researchers that communication by authorities to the public should include explicit information about uncertainties associated with events. It is important to ensure that the information provided is consistent and not contradictory, and is presented clearly and in an easy to understand manner.	Holmes (2009); Pappenberger (2013); Quinn (2008); Taylor-Clark (2007); Massé (2011) FR; Li (2010) CH	Moderate	Overlapping findings by 6 studies, individually appraised as high (2), moderate (3), and low (1).

QL	In France, Russia, and the United States, for flood, hurricane, and general public health events, and for preparation and onset phases as well as evaluation, uncertainty information provided in messages as predictor is associated with the outcomes of: confidence in forecasts; reduction in circulation of misinformation; and improved risk management. However, the uncertainty about specific parameters of an event may sometimes leave not have enough time to prepare property or move belongings to a safe location. Also, the phrasing of the uncertainty information may sometimes be interpreted negatively, which may affect response to future risk communication.	Morss & Hayden (2010); Duchêne (2004) FR; Gryzunova (2012) RU	Moderate	Overlapping findings by 3 studies, individually appraised as high (1), moderate (1), and low (1)
QL	In the United States, for flood event, and for onset phase, how experts make decisions about forecasting and warnings under conditions of uncertain data is a complex process. Experts have to use (scientifically) uncertain data, and in rapidly evolving situations where multiple actors have to make interrelated decisions under uncertainty, there is a greater danger of risk assessment propagating across individuals in unintended ways. Although uncertainty can be reduced by actively seeking and obtaining data from multiple sources, there is a need to improve experts' decision-making under conditions of uncertain data in the context of their interactions with others.	Morss (2015)	Moderate	Finding based on one study, appraised as high.
MM, CS	In Russia and the United States, for flood and general public health events, and for preparation phase, there are several types of uncertainty information that can be put in messages by authorities. In particular, these include knowledge uncertainty (limitations of scientific understanding of complex natural processes and future changes) and sampling uncertainty (uncertainty in estimates calculated using limited data samples from naturally variable processes). The uncertainties can also be about results of checks and examinations of event control mechanisms and health affecting properties of dangerous materials produced by industry. It should be noted that often uncertainty becomes confounded with values issues, which deal with the appropriate standards of public protection.	Downton (2005); Podkorytov (2014) RU	Moderate	Overlapping findings by 2 studies, both individually appraised as high.

MM, CS	In Chile and Indonesia, for flood and landslide events, for preparation phase, and including for low SES people, for authorities to develop messages that contain uncertainty information, it is important to keep in mind the whole living environment of the intended audience, which may be full of uncertainties due to poverty. It should be recognized that issues of development and environment are just as central to reduced uncertainty as messages from authorities.	Aldunce (2007); Voorst (2015)	Moderate	Overlapping findings by 2 studies, both individually appraised as moderate.
MM, CS	In Chile, Finland, Singapore, South Africa, and New Zealand, for air pollution, earthquake, infectious disease, industrial accident, landslide, and general public health events, for all phases as well as evaluation, uncertainty experienced by the public as an outcome is associated with the following predictors: disaster management, coordination, and cooperation at the local level; disaster management plan that is interactive with the public, and that includes all mass and social media; integrated management of official response to event across all mass and social media and other domains; regular and timely information, including via social media; detailed information disseminated, including through personal networks (doctors, nurses, community leaders); regular updates about the event progression through the mass media; information about the probability and consequences of events; and differing levels of risk perceptions.	Aldunce (2007); Dabner (2012); Karan (2007); Skinner (2014); Barengo (2011) SP; Francescutti (2007) SP; Vallejos-Romero (2013) SP	Moderate	Overlapping findings by 7 studies, individually appraised as high (4), moderate (1), and low (2)
MM, CS	In Canada and France for an infectious disease event, and for onset and containment phases, uncertainty about an event conveyed by mass media coverage through rapidly changing, contradictory, and conflicting information, especially that differs from official information from authorities, increases uncertainty and fear in the public, and puts a constraint on health/medical workers ability to address the public's uncertainty.	Rousseau (2008)	Moderate	Finding based on one study, appraised as moderate.

MM, CS	In Canada, France, and Israel, for infectious disease event, and for onset and containment phases, and for medical/ health care workers and policy makers. As a result of absent or contradictory and inconsistent information from authorities, medical/ health care workers and policy makers experience uncertainty and the organizational decision making regarding communication to the public becomes uncertain. Instead of providing transparent communication regarding the uncertainty surrounding an emergent event, if authorities rush to declare a "fact" about the event without adequate information, it can lead to compromised decision making and efforts by organizations.	Gesser-Edelsburg (2014); Rousseau (2008)	Moderate	Overlapping findings by 2 studies, both individually appraised as moderate.
MM, CS	In Austria, Belgium, Canada, Norway, Russia, South Africa, the United Kingdom, and several European countries, for flood, infectious disease, industrial accident, and general public health, and for all four phases as well as evaluation, uncertainty information in messages provided by authorities as predictor is associated with the following outcomes: reduced experienced uncertainty; reduced uncertainty about protection actions; avoidance of information void; reduced misinformation; prevention of rumors; reduced indifference; reduced reliance on sensationalized stories; increased sense that situation is under control; and efficiency, quality, and value of forecasts. The uncertainty information should be timely, full, and unbiased.	Ramos (2010); Skinner (2014); Jakubowski (2004) FR; Lord (2009) FR; Pozdnyakov (2011) RU	Moderate	Overlapping findings by 5 studies, individually appraised as high (4) and low (1).
MM, CS	In the United States, for food contamination event, and for preparation phase, experts/scientists indicate that providing information about scientific uncertainty will have a negative impact on the extent to which the public trusts science, scientists, and scientific institutions; their view is that the general public is unable to conceptualize uncertainties associated with risk management processes and so providing the public with information about uncertainty will cause panic and confusion regarding the extent and impact of a particular event.	Frewer (2003)	Moderate	Finding based on one study, appraised as high.

MM, CS	In several European countries and the United States, for flood events, and for preparation phase as well as evaluation, uncertainty of data and knowledge influences decision making and interactions within and among groups of experts and between experts and policy/ decision makers. It is important to see a final policy decision as the end point of a chain of decisions that includes a flow of uncertainty information. It is also important to assess how different people in the decision chain perceive and understand uncertainty, and tend to act in face of uncertain information. For example, policy/ decision makers may not fully understand scientific uncertainty and may default to their intuitions and experience to make decisions. Additionally, uncertain scientific knowledge is entwined with values issues (appropriate standards for public protection), which makes the decision chain process more complex.	Downton (2005); Morss (2010); Ramos (2010)	High	Overlapping findings by 3 studies, all individually appraised as high.

Notes. (back to text)
Method: Quantitative-Comparison Groups (QN-CG); Quantitative-Descriptive Survey (QN-DS); Qualitative (QL); Mixed-Method/ Case Study (MM, CS)
Citations-Language: English has no suffix; Arabic (AR); Chinese (CH); French (FR); Russian (RU); Spanish (SP)
Certainty/ Confidence Evaluation: QN-CG (GRADE) – High; Moderate; Low; Very low; QN-DS (GRADE Adapted) – High; Moderate; Low; Very low; QL (CERQual) – High; Moderate; Low; Very low; MM, CS (as appropriate) – High; Moderate; Low; Very low

Table 6. *Synthesis of Findings Across Methodological Streams* (back to text p.12, p.14)

Synthesized Finding Across Method Streams (with subgroup analysis of type, phase, and country of disaster, and vulnerable population)	Citations (first author only, unless noted otherwise) Supporting Synthesized Finding Across Method Stream	Evaluation of Certainty/ Confidence[1]
There are several different types/ sources of uncertainty associated with an event, related to both uncertainties experienced by the public and also uncertainty information than can be put in messages, that authorities need to keep in mind. As some examples, uncertainty can be regarding: safety of person, home, and close others; event knowledge, sampling, data, and outcome; and influx of non-local people. Experience of uncertainty changes across the time course of an event that includes, for example, uncertainty regarding impact of event (onset, containment) and future of schools and village/ town and decisions about rebuilding (containment, recovery). It should be noted that, particularly for authorities, uncertainty can become confounded with values issues, which deal with the appropriate standards of public protection. The countries covered include France, Iran, New Zealand, Russia, Thailand, the United Kingdom, and the United States. Events include earthquake, flood, food contamination, industrial accident, tornado, volcanic, wildfire, and general public health. Preparation and recovery phases are covered along with evaluation. No vulnerable populations are included.	Afifi (2012); Afifi (2014); Alipour (2015); Downton (2005); Doyle (2011); Janmaimool (2014); Miles (2003); Duchêne (2004) FR; Podkorytov (2014) RU	QN-CG (GRADE): --- QN-DS (GRADE Adapted): Low to High QL (CERQual): Moderate to High MM, CS: Moderate to High

The public's experience of uncertainty is due to lack of information. Uncertainty is reduced by greater information and the public actively seeks out information to reduce its uncertainty. Thus, information from authorities can reduce the public's uncertainty. People seek both general and specific information, and there are demographic and mass medium differences in information seeking; people also seek information (and coping support) from personal networks to reduce uncertainty and its impact on mental health. The uncertainty experienced by the public as an outcome is associated with other predictors as well, that, as examples, include: disaster management, coordination, and cooperation at the local level; disaster management plan that is interactive with the public, and that includes all mass and social media; integrated management of official response to event across all mass and social media and other domains; speedy, regular, timely, reliable, and detailed information about event progression, including via social media and personal networks (doctors, nurses, community leaders); regular updates about the event progression through the mass media; and differing levels of risk perceptions. The countries covered include Australia, Chile, China, Finland, Japan, Mexico, New Zealand, Singapore, South Africa, the United Kingdom, and the United States. Events include air pollution, earthquake, floods, hurricane, industrial accident, infectious disease, landslide, tornado, wildfire and general public health. All four phases of an event are covered along with evaluation. School children as vulnerable populations included.	Acar (2011); Afifi (2012); Afifi (2014); Aldunce (2007); Bird (2012); Burke (2009); Dabner (2012); Karan (2007); Skinner (2014); Spence (2007); Taylor-Robinson (2009);Barengo (2011) SP; Francescutti (2007) SP; Muniz (2011) SP; Vallejos-Romero (2013) SP	QN-CG (GRADE): --- QN-DS (GRADE Adapted): Low to High QL (CERQual): Moderate to High MM, CS: Moderate

There is general agreement among experts and researchers that communication by authorities to the public should include explicit information about uncertainties associated with events. It is important to ensure that the information provided is consistent and not contradictory, and is presented clearly and in an easy to understand manner. However, in contrast, some experts/ scientists indicate that providing information about scientific uncertainty can have a negative impact on the extent to which the public trusts science, scientists, and scientific institutions; they view the general public as unable to conceptualize uncertainties associated with risk management processes and so providing the public with information about uncertainty will cause panic and confusion regarding the extent and impact of a particular event. Countries covered include Canada, China, European Union countries, New Zealand, Thailand, the United States, and general globally. Events include bioterrorism, floods, foodborne illness, industrial accident, infectious disease, volcanic, and general public health. Preparation, onset, and containment phases are covered, with emphasis on preparation, along with evaluation. Low SES minorities, pregnant women, children, and people with chronic disease vulnerable populations are included.	Doyle (2011); Frewer (2003); Holmes (2009); Janmaimool (2014); Pappenberger (2013); Quinn (2008); Taylor-Clark (2007); FAO/WHO (2011) FR; Massé (2011) FR; Li (2010) CH	QN-CG (GRADE): --- QN-DS (GRADE Adapted): Low to Moderate QL (CERQual): Moderate MM, CS: Moderate
To develop messages that contain uncertainty information, it is important to keep in mind the whole living environment of the intended audience. People's lives may be full of uncertainties due to poverty and not just because of a particular hazard. It should be recognized that issues of development and environment are just as central to reduced uncertainty regarding an event as messages from authorities. Countries covered include Chile and Indonesia. Events are flood and landslide, and the phase is preparation. Low SES vulnerable populations are included.	Aldunce (2007); Voorst (2015)	QN-CG (GRADE): --- QN-DS (GRADE Adapted): --- QL (CERQual): --- MM, CS: Moderate

Uncertainty information in messages provided by authorities is generally associated with desirable outcomes but the possibility of some undesirable outcomes needs to be kept in mind. Some positive outcomes include: Reduced experienced uncertainty; reduced uncertainty about health protection actions; reduced information void, circulation of misinformation and rumors, and reliance on sensationalized media stories; improved efficiency, quality, and value of forecasts; and improved response to future warnings. However, openly acknowledging uncertainties in messages may reduce trust in authorities. But, this decrease is only for a small proportion of the total number of message recipients; for the vast majority of message recipients, there is no change in their level of trust. Additionally, the uncertainty about specific parameters of an event may sometimes leave the public not have enough time to prepare property or move belongings to a safe location. Also, the phrasing of the uncertainty information may sometimes be interpreted negatively, which may affect response to future risk communication. Countries covered are Canada, European Union countries, India, New Zealand, Norway, Russia, South Africa, Thailand, the United Kingdom, and the United States. Events are bioterrorism, cyclone/ hurricane, earthquake, flood, food contamination, general public health, industrial accident, and infectious disease. All four phases along with evaluation covered. Low SES minorities vulnerable populations included.	Janmaimool (2014); Johnson (2015); McClure (2015); Miles (2003); Morss & Hayden (2010); Sharma (2012); Ramos (2010); Skinner (2014); Vaughan (2012); Duchêne (2004) FR; Gryzunova (2012) RU; Jakubowski (2004) FR; Lord (2009) FR; Pozdnyakov (2011) RU	QN-CG (GRADE): Low to Moderate Low to ModerateQN-DS (GRADE Adapted): QL (CERQual): Moderate MM, CS: Moderate to High
The public's understanding of some uncertainty information associated with event likelihood estimates is error prone. This error is true of experts (scientists, non-scientists) as well. The likelihood of event occurrence is rated higher in later intervals than in earlier intervals of a time window; the likelihood of event occurrence is not understood as being uniform throughout a time window. For example, the likelihood of an event occurrence in a 3-day time window is rated higher toward the end interval and lower in the first interval of the window, as opposed to uniform across all periods in the time window. Additionally for experts, translation of verbal descriptions of event likelihood uncertainty to numerical terms is not fully accurate. Country covered is New Zealand. Events are earthquake and volcanic. Phase covered is preparation. No vulnerable populations are included.	Doyle (2011); Doyle (2014); McClure (2015)	QN-CG (GRADE): --- QN-DS (GRADE Adapted): Low to Moderate QL (CERQual): --- MM, CS: ---

Uncertainty of data and knowledge influences interactions within and among groups of experts and between experts and policy/ decision makers and this affects the decision-making process in complex ways. It is important to see a final decision (e.g., evacuation warning) as the end point of a chain of decisions that includes a flow of uncertainty information. Experts have to use (scientifically) uncertain data, and in rapidly evolving situations where multiple actors have to make interrelated decisions under this uncertainty, there is a greater danger of risk assessment propagating across individuals in unintended ways. Different people in the decision chain perceive and understand uncertainty, and tend to act in face of uncertain information,, differently. For example, policy/ decision makers may not fully understand scientific uncertainty and may default to their intuitions and experience to make decisions. Additionally, uncertain scientific knowledge is entwined with values issues (appropriate standards for public protection), which makes the decision chain process even more complex. Countries covered include several European countries and the United States. Event is floods, and preparation and onset phases are covered along with evaluation. No vulnerable populations are included.	Downton (2005); Morss (2010); Morss (2015); Ramos (2010)	QN-CG (GRADE): --- QN-DS (GRADE Adapted): --- QL (CERQual): Moderate MM, CS: Moderate to High
Mass media coverage of an event that emphasizes rapidly changing, contradictory, and conflicting information, especially that differs from official information from authorities, increases uncertainty in the public, which in turn can lead to several undesirable outcomes. These include: lack of trust in authorities and recommended actions; confusion and fear; reduced intentions for health protective behaviors such as vaccination; and reduced attention to health risk news. Such media coverage also puts a constraint on the ability of frontline health/medical workers to address the public's uncertainty. Countries covered are Canada, France, and the United States. Events are bioterrorism, infectious disease, tornado, and general public health. All four phases are covered. Low SES minorities vulnerable population included.	Afifi (2014); Quinn (2008); Rousseau (2008); Taylor-Clark (2007)	QN-CG (GRADE): --- QN-DS (GRADE Adapted): --- QL (CERQual): Moderate to High MM, CS: Moderate

As a result of absent or contradictory and inconsistent information from authorities, medical/ health care workers and policy makers experience uncertainty and the organizational decision making regarding communication to the public becomes uncertain. Instead of providing transparent communication regarding the uncertainty surrounding an emergent event, if authorities rush to declare a "fact" about the event without adequate information, it can lead to compromised decision making and efforts by organizations. Countries covered are Canada, France, and Israel. Event is infectious disease. Onset and containment phases are covered. No vulnerable populations are included.	Gesser-Edelsburg (2014); Rousseau (2008)	QN-CG (GRADE): --- QN-DS (GRADE Adapted): --- QL (CERQual): --- MM, CS: Moderate

Notes. (back to text p.12, p.14)

Citations-Language: English has no suffix; Arabic (AR); Chinese (CH); French (FR); Russian (RU); Spanish (SP)

Certainty/ Confidence Evaluation: QN-CG (GRADE) – High; Moderate; Low; Very low; QN-DS (GRADE Adapted) – High; Moderate; Low; Very low; QL (CERQual) – High; Moderate; Low; Very low; MM, CS (as appropriate) – High; Moderate; Low; Very low

[1] Only English language studies considered.

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