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Review article

# Main factors influencing the perceived health risk of endocrine-disrupting chemicals: A systematic literature review☆

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ABSTRACT

Endocrine-disrupting chemicals (EDCs) are linked to rising health issues such as infertility, childhood obesity, and asthma. While some research exists on health risk perceptions of EDCs, a comprehensive understanding across different populations and contexts is needed. We performed a systematic literature review, examining 45 articles published between 1985 and 2023, focusing on both the risk perception of EDCs as a whole as well as individual EDCs found in the environment (e.g., pesticides, bisphenol A, and phthalates). We identified four major categories of factors influencing EDC risk perception: sociodemographic factors (with age, gender, race, and education as significant determinants), family-related factors (highlighting increased concerns in households with children), cognitive factors (indicating that increased EDC knowledge generally led to increased risk perception), and psychosocial factors (with trust in institutions, worldviews, and health-related concerns as primary determinants). This review highlights the complex nature of EDC risk perception, shaped by socio-demographic, family, cognitive, and psychosocial factors, essential for policymakers in crafting educational and communication strategies. Future research should expand to cover more EDCs, use representative samples, and explore the influence of psychosocial factors on risk perception more deeply.

## 1. Introduction

The latest trends show that infertility affects roughly one in every six people worldwide (World Health Organization, 2023a). Childhood obesity rates have risen from 2% in 1990 to 8% in 2022, now affecting 160 million children and adolescents (World Health Organization, 2023c). Asthma, the most common chronic disease among children, affected 262 million people globally in 2019 and caused 455,000 deaths (World Health Organization, 2023b). These health trends, though seemingly unrelated, appear to be linked by a common factor: exposure to endocrine-disrupting chemicals (EDCs) (Barouki et al., 2012; Bølling et al., 2020; Braun, 2017). EDCs are substances that interfere with the normal function of the body's endocrine system (Endocrine Society, n.d.-b). There are thousands of EDCs in the environment, and people are widely exposed to them in their daily lives (European Environment Agency, 2023). Common EDCs include pesticides (e.g., in foods), bisphenol A (BPA) and phthalates (e.g., in plastics), and parabens (e.g., in personal-care products) (Endocrine Society, n.d.-a). Due to their disruption of hormones, EDCs have been associated with negative effects on the reproductive and endocrine systems, metabolism, and cancers (Casals-Casas and Desvergne, 2011; Diamanti-Kandarakis et al., 2009). A recent review even established a causal link between several EDCs (e.g., BPA) and obesity (Heindel et al., 2022).

EDCs are likely to have disrupting effects even at very low doses (Barouki et al., 2012). Furthermore, exposure to EDC mixtures—combinations of different EDCs—can result in additive or synergistic effects, a phenomenon often referred to as the 'cocktail effect,' which can lead to significant negative health impacts (Delfosse et al., 2015; Kortenkamp, 2007). EDCs are a major public health hazard, costing the EU an estimated €157 billion in health impacts each year (Trasande et al., 2015). According to the World Health Organization (WHO), EDCs represent "a global threat that needs to be resolved" (World Health Organization, 2012, p. 27). Despite the recognized risks, regulatory actions can be slow. It can take up to 30 years for the EU to

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ban a suspected endocrine-disrupting substance (Eriksen and Uhrenholt Kusnitzoff, 2017). Even after a ban, these chemicals can still be found in consumer products (Søgaard Kirkeby, 2021), indicating a lag in market response to regulations. Thus, while regulatory actions are critical, our individual choices—such as food consumption and the use of personal-care and cosmetic products—can also have a significant impact on our level of EDC exposure. Therefore, to effectively reduce EDC exposure, both regulatory actions and individual behavior changes are necessary. To achieve behavior changes, we must first address the issue of how people perceive health risks associated with EDCs.[1] Previous research has shown that health risk perceptions are consistently related to actual health-related intentions and behaviors across multiple domains (N. T. Brewer et al., 2007; Dillard et al., 2012; Floyd et al., 2000; Schneider et al., 2021), and that interventions that change risk perceptions change health behaviors (Ferrer and Klein, 2015).

Research on EDCs in health sciences is expanding (Gore et al., 2015), and findings are shared through media (Kjeldgaard Kristensen, 2021), popular science books (Demeneix, 2017), or communicated by governments (e.g., leaflets to pregnant women) (Bay et al., 2014) and NGOs (Jørgensen, 2019). However, while research has explored people's perceptions of health risks associated with EDCs, no comprehensive reviews have synthesized these findings. In light of this, our goal was to investigate how these risks are perceived across different populations and contexts. Specifically, we conducted a systematic literature review and identified four main factors influencing the health risk perception of EDCs (i.e., sociodemographic, family-related, cognitive, and psychosocial factors). Our systematic review provides a comprehensive understanding of the current state of knowledge on EDC risk perception and it identifies gaps in the literature. A better understanding of the main factors behind EDC risk perception should inform effective risk communication strategies. Furthermore, based on our findings, we propose ideas for future research, identifying areas that require deeper investigation and understanding. Our review could also help policymakers and public health authorities ensure that EDC regulation, guidelines, and interventions are both scientifically sound and in line with individual EDC risk perceptions.

## 2. Method

### 2.1. Literature search strategy

We adhered to the PRISMA 2020 checklist to conduct and report the review (Page et al., 2021). On August 25, 2022, AP conducted initial search. The goal of this step was to compile a primary pool of articles, which would aid in defining the search terms. The Google Scholar database was selected for this purpose because it contains a broad range of scientific literature. The search was limited to the first five pages and was not restricted by publication year. It was conducted by combining terms from two search categories.

The first category included the following terms: "bisphenol A," "BPA," "brominated flame retardants," "phthalates," "polychlorinated biphenyls," "parabens," "pesticides," "per- and polyfluoroalkyl substances," and "PFAS." The second category included the terms "risk perception" and "risk communication". We used all possible combinations of search terms from the first and second categories. To be eligible, articles needed to contain terms from both categories simultaneously. Duplicates were manually removed by AP. The relevance of the articles was assessed by reviewing the abstracts. Abstracts were independently read by AP and SP. After reviewing the abstracts, 150 out of 171 articles were excluded due to irrelevance. The remaining relevant articles were read in full. After the preliminary analysis, we found that the majority of relevant articles contained findings on EDC risk perception. Therefore, we decided to narrow our scope to exclusively risk perception and excluded six additional articles that did not present findings related to this topic. In total, 15 articles were found to be relevant after the initial search.

Based on the articles from the initial search, we identified frequently used keywords and phrases for constructing a relevant search statement for the defined search. Our goal was to develop a search statement that would exclude irrelevant articles while producing a sufficient number of potentially relevant ones. To eliminate irrelevant articles and reduce the total number of results, we conducted a series of consecutive searches in the Web of Science database. We gradually removed the broadest terms that generated the most results with the least specificity. For example, excluding the term "health risk*" from our search, we were able to decrease the number of results by over 5000. Similarly, omitting the term "attitude*" reduced the results by almost a thousand.

For our defined search, we utilized the Web of Science database due to its comprehensive coverage of multidisciplinary articles. We employed a dual-category search strategy. The first category encompassed general and specific EDCs, using terms such as "endocrine disrupt*," "bisphenol A," "phthalate*," "paraben*," "pesticid*," "brominated flame retardant*," "polychlorinated biphenyl*," "perfluoroalkyl*," "polyfluoroalkyl*," and "PFAS." These specific EDCs were selected from the Endocrine Society's list of common EDCs frequently encountered in daily life (Endocrine Society, n.d.-a). The second category targeted risk perception, incorporating terms like "risk perception", "perception of risk", "perceived risk", "feeling of risk", "risk attitude", and "risk belief". We crafted the search statement to capture any combination of terms from both categories. We imposed no date restrictions, thus considering all articles published up to September 01, 2023. Eligibility required articles to contain terms from both categories. For the precise search statement, please refer to the OSF project page.

For comprehensiveness, we replicated the search in the PubMed database, following the same methodology and logic, with the search statement designed to identify any combination of terms from the two categories, considering articles up to September 01, 2023. Eligibility criteria were consistent with the Web of Science search. The search statement for PubMed is available at the OSF project page.

AP and SP independently screened all articles that met the search criteria by reviewing the full texts. Discrepancies were resolved through discussion. Additionally, a reference search of the articles selected by AP and SP yielded thirteen additional articles for inclusion in the review.

### 2.2. Eligibility criteria

Articles that fulfilled the following inclusion criteria were considered: 1) The research topic was related to both risk perception and EDCs. 2) The risk perception of at least one specific EDC or EDCs as a category was quantified or qualitatively assessed. 3) The study sample focused on a general public with no specific knowledge of the subject and was not limited to a specific profession (e.g., medical doctors, nurses, midwives, farmers) or hobby/interest (e.g., fishermen, anglers). 4) The article was written in English. 5) The article presented the findings of their own research. 6) The article was published in a peer-reviewed journal.

### 2.3. Data extraction

We created a data-extraction form based on the research question. During the preliminary analysis, we coded all findings related to the following variables: subjective knowledge about EDCs, EDC risk perception, actual and intended behavior related to EDCs, EDC risk communication, and actual levels of EDC exposure. However, because we narrowed our search to EDC risk perception, we extracted only the findings relevant to this topic in the final version of the form. Specifically, we coded all the information related to the risk perception of EDCs as a general category and specific EDCs of interest that were

[1] Throughout the article, when we refer to the risk perception associated with EDCs, we are referring to the health risk perception, but for the sake of brevity, we do not always state this explicitly.

relevant to answering our research question. This included information such as the level of concern or worry related to EDCs, as well as perceived severity or susceptibility to EDCs. We also coded information about the publication year, research aim, EDC type, research method (e.g., survey, interview, experiment, etc.), sample (e.g., specific group or entire population), sample size, and study origin. AP and SP independently read all the studies. AP did the initial data coding. SP then reviewed and edited the coded data. AP then reviewed all the changes. The authors resolved disagreements through discussion. Finally, to avoid the possibility of mistakes in the extracted data, we used the AI tool "Elicit: The AI Research Assistant" to double-check our coding (https://elicit.com/). It was used for extracting the following information: authors, year, number of participants, and region. We found no mistakes in the extracted data.

### 2.4. Quality assessment

The risk of bias in the included studies was independently assessed by AP and SP. Because the majority of the quantitative studies in the review are survey-based, we used the tool called "Critical Appraisal of a Questionnaire Study" to evaluate them (Roever, 2015). Like JBI's critical appraisal tool for cohort studies (Moola et al., 2020), "CASP" Checklist for cohort studies (Critical Appraisal Skills Programme, 2018), or "The Mixed Methods Appraisal Tool" (MMAT) (Hong et al., 2018), the "Critical Appraisal of a Questionnaire Study" allows evaluating the main domains of the study: validity, reliability, research design, sample, risk of bias, and data analysis used. However, unlike the other mentioned tools, "Critical Appraisal of a Questionnaire Study" was designed specifically for survey-based research, so it does not require any further adjustments and allows us to assess other specific aspects, such as response rate or distribution method. We assessed the following aspects: validity, reliability, distribution method, piloting, response rate, response bias, sample representativeness, example questions, data analysis and results details, limitations, and conflict of interest. Each study was assessed using these aspects, and "1″ stood for "study met the criteria" and "0″ for "study did not meet the criteria". An overall score was used to assess the quality of the studies. The inter-rater agreement for quantitative studies was 0.830, which indicates a high extent of coder agreement. Disagreements between the coders were resolved through discussion.

For qualitative studies assessment, we used the "CASP Qualitative Studies Checklist" (Critical Appraisal Skills Programme, 2022). The following aspects were assessed: research design, recruitment, data collection, relationship between researcher and participants, ethics, data analysis, findings, and contribution. Each study was assessed using these aspects, and "1″ stood for criteria fulfilled, whereas "0″ stood for criteria not fulfilled. The inter-rater agreement for qualitative studies was 0.539, which indicates a moderate extent of coder agreement. Disagreements between the coders were resolved through discussion.

Finally, for intervention studies (i.e., a randomized control trial and a quasi-experimental field study), we used the relevant tools developed by JBI: the 'JBI Critical Appraisal Tool for Assessment of Risk of Bias for Randomised Controlled Trials' and the 'Checklist for Quasi-Experimental Studies (Non-randomized Experimental Studies)' (Barker et al., 2023; Tufanaru et al., 2017). The inter-rater agreement for intervention studies was 0.736, which indicates a moderate extent of coder agreement.

Again, disagreements between the coders were resolved through discussion. All quality assessment data is available at the OSF project page.

Additionally, we found that questions measuring risk perceptions were not explicitly provided in three articles, so we contacted the corresponding authors. Emails were sent to the addresses listed in the articles; for the two articles without provided emails, AP retrieved them through an online search. We received one answer from the authors.

### 2.5. Transparency and Openness

All extracted data and research materials, such as search statements and quality assessment details, are available on the Open Science Framework and can be accessed through the following link: OSF project page.

## 3. Results

### 3.1. Study selection and Characteristics

In total, 45 articles were included in the review. The PRISMA flowchart, which shows the search process, is depicted in Fig. 1. For an overview of the details regarding the included studies, see Table 1. For a more comprehensive overview, we refer the reader to the OSF project page.

### 3.2. Syntheses

#### 3.2.1. Chronological distribution and topics

All the studies were published in the period between 1985 and 2023. The chronological distribution of studies revealed an increasing interest in this topic. Distribution by theme (specific EDC) has also changed over time: prior to 2010, nearly all studies were focused on pesticides; after 2010, the proportion has changed, with an increasing interest on the risk perception of other EDCs. An overview of the distribution of studies by year of publication and specific EDC examined can be found in Table 2.

The geographic distribution of studies has evolved; before 2000, most were conducted in the USA, but over time, research has expanded to Europe and other countries. An overview of the distribution of studies by year of publication and geographical location can be found in Table 3.

#### 3.2.2. Methods

The majority of the studies (36 in total) employed quantitative methods and the most common method employed involved face-to-face and telephone surveys. Qualitative methods were utilized in five studies, while another four adopted a mixed-methods approach, integrating both qualitative and quantitative methods. The most common qualitative methods used were interviews (e.g., semi-structured and in-depth) and focus groups. Additionally, two studies were classified as intervention studies. These included a randomized control trial and a quasi-experimental field study with one intervention and one control group.

#### 3.2.3. Sampling and participant characteristics

The studies reviewed encompassed a diverse range of target populations. Of these, 34 focused on the general adult population across different countries (see Tables 1 and 3 for details). Additionally, 11 studies focused on specific populations like students, women, parents, or residents of contaminated areas and were evenly distributed across geographical locations (i.e., the United States, Europe, and other regions). The sample sizes varied, with the smallest being 10 and the largest being 4014.

#### 3.2.4. Measurements

Among the quantitative studies, the ordinal scale emerged as the predominant scale type for measuring EDC risk perceptions, being used in 31 studies. Within these, 16 utilized Likert-type scales, eight employed scales without a neutral option, five utilized unlabeled scales (lacking any endpoints), and two featured labels only at the endpoints. Meanwhile, nominal scales were adopted in seven studies, three of which were dichotomous. The majority of the studies gauged the level of agreement with a statement regarding risk perception. In contrast, the remaining studies employed specific adjectives to capture participants' attitudes towards EDCs, such as: unsafe/safe, not risky/very risky, not harmful/very harmful, not at all serious/very much so, not at all

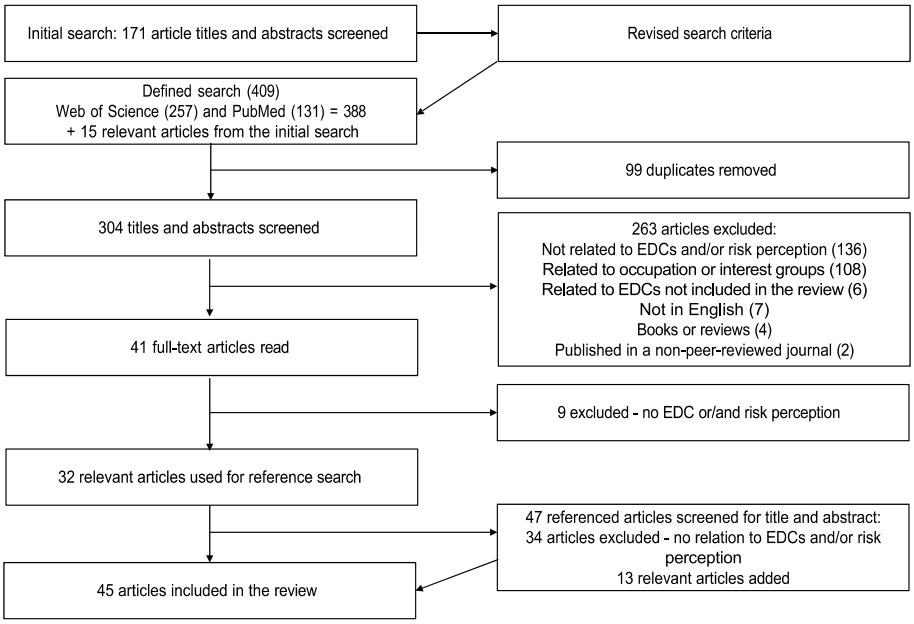


**Fig. 1.** PRISMA flow diagram of the study selection process for a systematic literature review on health risk perception of endocrine-disrupting chemicals.

worried/very much so, or not at all concerned/very concerned.

In qualitative studies, interview guides/topic guides were most commonly used to structure the discussion and ensure that all relevant topics were covered while allowing for the exploration of emergent themes. These guides helped in capturing relevant insights into participants' perceptions, attitudes, and experiences regarding EDC risks. To enhance the depth of the findings, all studies incorporated direct quotes from participants. In intervention studies, the primary measurements included scales and assessments of biological markers, specifically changes in EDC levels in urine samples.

Following the view that there are two fundamental ways regarding how people comprehend risks — namely, the "analytic system" corresponding to the cognitive dimension, which involves algorithmic and normative rule-based processing, and the "experiential system" corresponding to the affective dimension, which encompasses intuitive, fast, and mostly automatic processing (Slovic et al., 2004) — we analyzed which dimension of risk perception – cognitive or affective – was the main focus in the reviewed studies. Based on how the risk perceptions were measured, we classified them as either cognitive (e.g., probability of risk or seriousness of consequences if risk occurred) or affective (emotional response to risk, such as worry, fear, etc.). Among them, 25 studies explored the cognitive dimension, whereas six explored the affective dimension. Some studies simultaneously measured both the cognitive and affective dimensions of EDC risk perception (n = 14); however, none of them assessed the extent to which each dimension contributes to EDC risk perception.

In terms of the context in which EDC risk perceptions were examined, 27 studies focused on EDCs in food/water, seven on EDCs in the environment, six on EDCs in consumer products, and five on EDCs from multiple sources.

Finally, we found that most studies did not specify a specific time frame (n = 34).

In the remaining studies, time was delineated as "before, during, and shortly after pregnancy" (n = 5), "before/after the intervention" (n = 2), "now and the near future" (n = 1), a span of six months (n = 1), or based on perceptions of short-term versus long-term effects (n = 2).

### 3.2.5. Quality assessment

A comprehensive quality assessment of quantitative, qualitative, and intervention studies included in the review was independently performed by AP and SP. According to the "Critical Appraisal of a Questionnaire Study" tool (Roever, 2015) all the studies had acceptable or high quality. Although our assessment identified certain weaknesses in the included studies, none were excluded from the review. These weaknesses include the following aspects: Only 15% of the studies had fully representative samples of the general population, pilot details were provided in 26% of the studies, reliability and validity were claimed in 28% and 31% of studies respectively, and the conflict of interest was discussed in 33% of the included studies. However, while only 15% of the studies had fully representative samples of the general population, 42.5% employed random sampling (this proportion rises to 50% when considering only those studies conducted on the general population). Regarding the studies with non-representative samples (n = 32), six of them used a convenience sample, eight of them focused on specific groups (i.e., pregnant women, students, pesticide users, and parents), and the remaining ones (n = 18) were characterised by oversampling or the exclusion of certain groups from the sample. While the results from these studies cannot be generalized to the entire population, they may be relevant to certain groups. When describing the results that could not be generalized to the entire population, we always specifically stated that in the text (e.g., "A study focusing on *women* revealed … ", 52% of *pesticide users* believed … "). On the other hand, strengths of the included quantitative studies were related to the clarity of describing their methods that is, all studies provided their research questions, 97% of the studies outlined the distribution method and questions used (which were clear and understandable), and finally, 95% of the studies reported both significant and non-significant results. The overall quality of the qualitative studies was assessed as high since the studies met most of the criteria from the relevant checklist. This was also the case for intervention studies, where all criteria were met, although there was one item, namely whether the outcomes were measured in a reliable way, that the authors did not have the expertise to evaluate, so this aspect was assessed as 'not clear'.

### 3.2.6. Factors influencing EDC risk perception

Given the high methodological variation among the included studies, we opted for a qualitative analysis. Notably, the majority of the studies suggest that EDCs are generally perceived as risky. Mean risk perception values surpass the scale's midpoint.

This is true for both EDCs as a general category (Rouillon et al., 2018;

**Table 1**
Overview of studies included in the systematic review on health risk perception of endocrine-disrupting chemicals.

| Authors | EDC type | Method | Sample specifics | Main findings | Risk perception component |
|---|---|---|---|---|---|
| Brewer and Ley (2011) | BPA | Survey (telephone) | Adult population, N = 946, USA | Age and familiarity with BPA were positively related to concern about BPA. Women expressed greater concern compared to men. The frequency with which people went online to obtain health information was positively related to concern about BPA. | Affective |
| Hovick et al. (2021) | BPA | Online experiment | Adult population, N = 623*, USA | Exposure to a high-threat message was positively associated with perceptions of hazards. | Cognitive |
| Jansen et al. (2020b) | BPA | Semi-structured interview | Adult population, N = 10*, Netherlands | Most participants understood chemical health risks, trustedDutch food safety regulations, and expected the government to ban high-risk substances. They associated BPA with potential hazards, believing specific effects would only be mentioned if evidence existed. | Cognitive |
| Jansen et al. (2020a) | BPA | Survey (online) | Adult population, N = 766, Netherlands | Respondents' ratings of BPA consistently exceeded the scale's midpoint of 3, indicating a more negative appraisal, across all outcomes: hazard severity, hazard worry, risk magnitude, and risk worry. Trust in food safety had a weak negative correlation with BPA concern. Both the value of natural food and attitudes towards plastic packaging showed moderate positive correlations with all BPA appraisal outcomes. | Cognitive & Affective |
| Mello and Hovick (2016) | BPA and Pesticides | Survey (online) | Mothers, N = 891, USA | Perceived severity and susceptibility of BPA and pesticides were positively correlated with exposure reduction behaviors, attitudes, perceived normative pressure, self-efficacy, and information seeking. | Cognitive |
| Viscusi et al. (2020) | BPA | Survey (online) | Adult population, N = 2797, USA | Better educated respondents were more likely to believe that they face a risk. | Cognitive |
| El Ouazzani et al. (2022) | EDCs | Randomized control trial + survey (f2f) | Pregnant women, N = 260, France | Intervention led to a significant increase in EDC risk perception. | Cognitive |
| Kelly et al. (2020) | EDCs | Focus groups | Adult population, N = 34, Northern Ireland | EDCs were perceived as a serious health threat, and participants did not feel much control over EDC exposure. Female participants were concerned for the children's health while remaining indifferent to their exposure. Participants with pre-existing health conditions were especially concerned. | Affective |
| Marie et al. (2016) | EDCs | Survey (self-administrated) | Pregnant women/non-pregnant women 18–45 years, N = 128, France | 55% of participants perceived a risk in using cosmetics during pregnancy, compared to 50% outside of pregnancy. | Cognitive & affective |
| Rouillon et al. (2017) | EDCs | Semi-structured interviews/survey (f2f) | Pregnant women/women in the postpartum period, N = 12/300, France | Perceived susceptibility varied depending on the target group (the pregnant woman, her fetus, the future newborn, teenagers, and adults). 70.9% of participants considered EDC risk to be high for women's health. Only few participants believed EDC risk to be negligible for children. | Cognitive |
| Rouillon et al. (2018) | EDCs | Semi-structured interviews/survey (f2f) | Pregnant women/women in the postpartum period, N = 12/300, France | Age and knowledge about EDCs were positively associated with EDC risk perception. | Cognitive |
| Wee et al. (2022) | EDCs | Survey (online and self-administrated) | Adult population, N = 140, Malaysia | No evidence that demographic characteristics significantly influenced the perception of EDC risk in water. | Cognitive & affective |
| Brankov et al. (2014) | Pesticides | Survey (online) | Adult population, N = 420, Serbia | Nearly 88% of participants found pesticide-free produce healthier, 68.18% believed pesticide risks were underrated, and 65.13% thought pesticides significantly endangered humans. | Cognitive |
| Brown et al. (2022) | Pesticides | In-depth interview | Female caregivers, N = 20, Cambodia | Pregnant women, their fetuses, and postnatal children were perceived to be at particular risk. | Affective |
| Bruhn et al. (1991) | Pesticides | Survey (f2f) | Adult population, N = 479, USA | Pesticides were found to be the most frequent among the listed food concerns. | Affective |
| Calliera et al. (2019) | Pesticides | Survey (f2f) | Adult population, N = 215, Italy | 15% of respondents perceive pesticides as harmful to their health, a concern similar to risks from electromagnetic fields (13.7%), industrial fumes (13%), and domestic heating (10%). Pesticide risk perception decreases slightly with increased distance from agricultural fields. | Cognitive & affective |
| Chitra et al. (2013) | Pesticides | Survey (f2f) | Adult population, N = 143, India | Risk perceptions varied for pesticide-containing products like mosquito coils, liquid vaporizers, ant repellents, mothballs, and poison chalk. While nearly half of participants believed pesticide-containing products might harm their own and children's health, up to 20% considered them safe, and up to 67% were uncertain about their harmfulness. | Cognitive |
| Dosman et al. (2001) | Pesticides | Survey (telephone) | Adult population, N = 959/953, Canada | Higher risk perception was associated with female gender, older age, lower household income, having more children, and non-conservative political views. | Cognitive |
| Finucane et al. (2000) | Pesticides | Survey (telephone) | Adult population, N = 1204, USA | Females perceived greater pesticide risks to individuals and the public than males. Nonwhites perceived higher | Cognitive |

(*continued on next page*)

**Table 1** (*continued*)

| Authors | EDC type | Method | Sample specifics | Main findings | Risk perception component |
|---|---|---|---|---|---|
| | | | | public risks than whites. White males had the lowest perceptions of individual and public risks compared to white females, nonwhite males, and nonwhite females. | |
| Grieshop and Stiles (1989) | Pesticides | Survey (mail) | Adult population, N = 415, USA | Women were significantly more risk-averse than men. There was a positive correlation between perceived safety of pesticides, pesticide use, and the attitude that "pesticides are not toxic." | Cognitive |
| Hammonds (1985) | Pesticides | Survey (telephone) | Adult population, N = 1008, USA | 77% of participants perceived pesticide residues in food as a serious hazard. | Cognitive & affective |
| Hirsch and Baxter (2009) | Pesticides | Survey (mail) | Adult population, N = 1088, Canada | Participants with higher household incomes had lower perceptions of pesticide risk. Those with children aged 10 to 18 were more likely to believe pesticides posed a risk. | Cognitive |
| Knight and Warland (2005) | Pesticides | Survey (telephone) | Adult population, N = 1400, USA | Perceived risk of pesticides increased with knowledge, lower trust in the food system, being female, and belonging to a nonwhite race. Conversely, trust in science and more laissez-faire views about business reduced this perception. | Affective |
| Koch et al. (2017) | Pesticides | Survey (telephone) | Adult population, N = 1004, Germany | Organic consumers were more concerned about pesticide residues than conventional consumers. Unawareness of maximum allowed pesticide residue levels was associated with higher levels of concern about pesticide residues. | Cognitive & affective |
| Miles and Frewer (2001) | Pesticides | Semi-structured interview/survey (self-administrated) | Adult population, N = 26/309, UK | Pesticides were predominantly linked to health concerns, particularly regarding long-term and unknown effects. They were negatively perceived due to their chemical nature, with increased concerns for vulnerable groups, especially children and the elderly. | Cognitive |
| Muñoz-Quezada et al. (2019) | Pesticides | Quasi- experimental study + survey (self-administrated) | Parents-child pairs, N = 48, Chile | Educational intervention increased children's and parents' EDC risk perception. | Cognitive & affective |
| Nayga (1996) | Pesticides | Survey (telephone) | Adult population, N = 1112, USA | Younger people, more educated, males, residents of non-metro areas, and those with higher income perceived fewer risks of food with approved levels of pesticides. | Cognitive |
| Nieuwenhuijsen et al. (2005) | Pesticides | In-depth interview | Parents, N = 831, UK | Pesticide users perceived a lower risk from pesticides for themselves, children, and pets compared to non-users. | Cognitive |
| Ott (1990) | Pesticides | Survey (f2f) | Adult population, N = 315, USA | Older participants and college-educated shoppers expressed greater concern about pesticide use compared to their younger and non-college-educated counterparts, respectively. | Cognitive & affective |
| Rosati and Saba (2004) | Pesticides | Survey (f2f) | Adult population, N = 966, Italy | Personal risk perception and worry associated with pesticide residues were assessed, showing a positive correlation between the two. | Cognitive & affective |
| Saba and Messina (2003) | Pesticides | Survey (f2f) | Adult population, N = 947, Italy | Both consumers and non-consumers of organic food perceived pesticides as high risk. Trust in the institutions responsible for regulating the use of pesticides was important in understanding risk perceptions. | Cognitive |
| Schütz and Wiedemann (1998) | Pesticides | Survey (f2f) | Adult population, N = 408, Germany | Garden pesticides received the highest average risk ratings, with women's risk perceptions being slightly higher than men's. There was a positive correlation between personal and environmental risk perceptions. | Cognitive |
| Shepherd et al. (2012) | Pesticides | Survey (telephone) | Adult population, N = 1261, Australia | Older participants were more likely to perceive pesticides as harmful or very harmful to human reproduction compared to the 18–34 age group. Women perceived greater risks than men. | Cognitive |
| Simoglou and Roditakis (2022) | Pesticides | Survey (online) | Adult population, N = 1846, Greece | Women, urban dwellers, students, pesticide nonusers, and those with low confidence in plant-food safety certification were less likely to agree that "pesticides benefits outweigh risks". | Cognitive & affective |
| Tucker et al. (2006) | Pesticides | Survey (mail) | Adult population, N = 4014, USA | Pesticide residues in food had the highest perceived risk among seven categories; 32.6% of participants saw it as "serious", 38.6% "moderate", 25.8% "some risk", and 0.9% "no risk. | Cognitive & affective |
| Weaver et al. (1992) | Pesticides | Survey (f2f) | Adult population, N = 560, USA | 71% of participants expressed concerns about pesticide residues on fresh produce. Over 80% believed that chemical residues are personally harmful to consumers. | Cognitive |
| Williams and Hammitt (2001) | Pesticides | Survey (self-administrated) | Adult population, N = 711, USA | Lower trust in regulatory agencies, less education, older age, and female gender were associated with higher perceived risks from conventionally grown produce. | Cognitive |
| Zhang and Fan (2013) | Pesticides | Survey (self-administrated) | Students, N = 3069, China | 49.4% of participants ranked pesticides in food as a high risk (5th out of 15), with a moderate perceived health risk score. While 48% of males and 52.1% of females saw it as a high risk, this perception varied from 44.8% in municipalities to 51.3% in suburban/rural areas. | Cognitive |
| Banwell et al. (2020) | PFAS | Focus groups | PFAS affected adult population, N = 111, Australia | Physical health, especially the risk of cancer, was a primary concern for both participants' and their children's | Cognitive & affective |

(*continued on next page*)

**Table 1** (*continued*)

| Authors | EDC type | Method | Sample specifics | Main findings | Risk perception component |
|---|---|---|---|---|---|
| | | | | future health. Perception of one's poor health was linked to subjective vulnerability to PFAS. | |
| Girardi et al. (2022) | PFAS | Survey (online) | Mothers age 24–56, N = 384, Italy | The perceived risk of PFAS exposure was strongly related to trust in scientific (positively) and political institutions (negatively). | Cognitive |
| Lazarevic et al. (2023) | PFAS | Survey (mail) | Adult population, N = 881, Australia | Participants were concerned not only about themselves, but also about others. General psychological distress, somatization, and anxiety increased with increasing participants' concerns about physical and mental health. | Affective |
| Liu and Yang (2023) | PFAS | Online experiment | Adult population, N = 983, USA | Trust in government did not correlate with systematic risk processing, whereas trust in science showed a positive relationship with more systematic processing. This relationship was moderated by political ideology; specifically, trust in science was positively associated with systematic processing only among individuals with liberal political views. | Cognitive |
| Wickham and Shriver (2021) | PFAS | In-depth interview | Adult population, N = 20, USA | Participants expressed concerns about possible links between PFAS and their own health, particularly regarding various cancers, and increased concerns for the well-being of their children and potential adverse effects on future generations. | Affective |
| Dickson-Spillmann et al. (2009) | Phthalates | Survey (mail) | Adult population, N = 1234, Switzerland | Diet-related clusters significantly affected the perception of contaminants in food, with the two health-oriented clusters having higher risk perceptions than the two less health-oriented clusters. | Cognitive |

*Note.* Under "*," the sample size is specified for the EDC of interest; "EDC" stands for endocrine-disrupting chemical; "EDCs" under the "EDC type" column denotes that EDCs as a general category were the focus of a particular study; "f2f" denotes face-to-face interviews.

**Table 2**
Distribution of studies by their year of publication and specific endocrine-disrupting chemical examined.

| EDC/Year | 1985–1999 | 2000–2009 | 2010–2019 | 2020–2023 | Grand total |
|---|---|---|---|---|---|
| BPA | – | – | 1 | 4 | 5 |
| EDCs in general | – | – | 4 | 3 | 7 |
| Pesticides | 8 | 10 | 7 | 2 | 27 |
| PFAS | – | – | – | 5 | 5 |
| Phthalates | – | 1 | – | – | 1 |
| Grand total | 8 | 11 | 12 | 14 | 45 |

**Table 3**
Distribution of studies by their year of publication and geographical location.

| Year/Location | Europe | USA | Other countries | Grand total |
|---|---|---|---|---|
| 1985–1999 | 1 | 7 | – | 8 |
| 2000–2009 | 5 | 4 | 2 | 10 |
| 2010–2019 | 6 | 2 | 4 | 12 |
| 2020–2023 | 6 | 4 | 4 | 15 |
| Grand total | 18 | 17 | 10 | 45 |

Wee et al., 2022) and specific EDCs, such as pesticide residues in food (Bruhn et al., 1991; Flynn et al., 1994; Koch et al., 2017; Mello and Hovick, 2016; Ott, 1990; Rosati and Saba, 2004; Schütz and Wiedemann, 1998; Tucker et al., 2006), BPA (Jansen et al., 2020a; Mello and Hovick, 2016), and PFAS (Girardi et al., 2022). However, when it comes to non-dietary pesticide risk perceptions, they were either found to be moderate (Chitra et al., 2013; Nieuwenhuijsen et al., 2005; Zhang and Fan, 2013) or low (Calliera et al., 2019).

Additionally, we identified 10 factors that influence subjective risk perceptions of EDCs and classified them into four categories based on their similarities. These categories include sociodemographic factors (age, gender, race, education level, income level and occupation, and geographic and residential context), family-related factors (the presence of children in the household), cognitive factors (knowledge, awareness, and familiarity with EDCs), and psychosocial factors (trust in social institutions, worldviews, and health-related concerns). Each of these factors is discussed in greater detail in the respective subsections that follow.

### 3.3. Sociodemographic factors

#### 3.3.1. Age

Several studies have found a positive link between age and the risk perception of various EDCs, with older adults generally perceiving them as riskier than younger adults.

For instance, concern about EDCs such as BPA and pesticides was positively related to age, suggesting that older adults were generally more concerned about these substances than younger adults (P. R. Brewer and Ley, 2011; Ott, 1990). It was also found that older adults were more likely to perceive pesticides in food as a health risk (Dosman et al., 2001) and, more specifically, they perceived higher risks of pesticide residues in conventionally grown fruits and vegetables (Williams and Hammitt, 2001). However, Nayga (1996) found the opposite: older main meal planners were more likely to consider food grown with approved pesticide levels to be safe compared to younger ones. When discussing specific risks, older adults (>35) were significantly more likely than younger adults to believe that pesticides are harmful to human reproduction (Shepherd et al., 2012). Additionally, older women (>35) perceived higher health risks related to EDC exposure during pregnancy and the postpartum period compared to younger women during the same period (Rouillon et al., 2018).

#### 3.3.2. Gender

A number of studies have discovered a link between gender and the perceived risk of EDCs, with the majority of them finding that women perceive such risks to be higher than men. For example, women were more likely to be concerned about pesticides and perceived higher risks from pesticide-related hazards (Dosman et al., 2001; Finucane et al., 2000; Flynn et al., 1994; Grieshop and Stiles, 1989; Knight and Warland, 2005; Williams and Hammitt, 2001). Furthermore, women were almost twice as likely to consider pesticides to be harmful or extremely harmful

to human reproduction (Shepherd et al., 2012), as well as less likely to believe that the benefits of pesticides outweighed the risks (Simoglou and Roditakis, 2022). Only in the study on Chinese college students were males and females equally likely to rate pesticides in food as high risk (Zhang and Fan, 2013). Women were also more concerned about the use of BPA in household products compared to men (P. R. Brewer and Ley, 2011). The study focused on women's cosmetic use also discovered that in terms of EDCs as a general category, more than half of women believed that using cosmetics during pregnancy may pose some risks, and about half believed that it is 'not safe' or 'not really safe' even outside of pregnancy (Marie et al., 2016).

#### 3.3.3. Race

We identified only three studies investigating the relationship between race and EDC risk perceptions, specifically regarding the risk perception of pesticides. The available evidence consistently suggests that race can influence pesticide risk perception. In all of the studies, black individuals (Knight and Warland, 2005) or non-whites (Finucane et al., 2000; Flynn et al., 1994) perceived greater risks from pesticides compared to white individuals.

#### 3.3.4. Education level

The level of education appears to influence individuals' perceptions regarding the risks of EDCs. Specifically, individuals with higher education levels often held more definitive views. For instance, when asked about their personal risks related to BPA, those with more education were less ambivalent. They were less likely to report uncertainty and more likely to perceive a risk than less educated individuals (Viscusi et al., 2020).

However, the opposite is true for pesticides. More educated respondents tended to perceive fewer risks associated with the consumption of conventionally grown produce and its production (Williams and Hammitt, 2001). Moreover, those with higher education levels were more inclined to believe that food grown using approved pesticide levels was safe, contrasting with the perceptions of less educated individuals (Nayga, 1996).

#### 3.3.5. Income level and occupation

Research suggests that there is a connection between one's income level and their perceptions about EDC risks. Specifically, individuals with higher income tended to perceive lower EDC-related risks. For instance, individuals with higher income were found to perceive fewer risks from pesticides (Dosman et al., 2001; Hirsch and Baxter, 2009) and were more likely to consider approved pesticide levels as safe (Nayga, 1996). When it comes to occupation, the results are mixed. Self-employed and retired individuals were more likely to perceive that the benefits of pesticides outweigh their potential risks compared to civil servants, private sector employees, or unemployed individuals (Simoglou and Roditakis, 2022). On the other hand, full-time employees expressed fewer concerns about the health risks of PFAS exposure compared to housewives or those who were unemployed (Girardi et al., 2022). Finally, individuals who were exposed to PFAS due to their occupation expressed concerns regarding potential long-term health outcomes (Banwell et al., 2020).

#### 3.3.6. Geographic and residential context

Residence has been found to influence risk perception in several studies. For example, students from municipalities perceived pesticides as less risky compared to those from suburban and rural areas (Zhang and Fan, 2013). Furthermore, main meal planners residing in areas with populations over 50,000 were less convinced of the safety of food with permitted pesticide levels than those in less populated areas (Nayga, 1996).

Moreover, residents of urban areas were less likely to believe the benefits of pesticides outweighed the risks (Simoglou and Roditakis, 2022). Finally, Calliera et al. (2019) found that the perceived risk of pesticides decreased slightly with increasing distance from agricultural fields.

### 3.4. Family-related factors

#### 3.4.1. Presence of children in the household

Several studies have discovered a link between the presence of children in the household and increased risk perceptions of EDCs, such that the individuals with children tended to perceive higher risks. For example, respondents were more likely to believe pesticides posed risks if they had at least one child aged 10 to 18 (Hirsch and Baxter, 2009). Furthermore, another study found that the more children present in a household, the greater the likelihood of respondents perceiving pesticides as health risks to household members (Dosman et al., 2001). A qualitative study targeting female caregivers found they particularly perceived pregnant women and their fetuses to be at risk from pesticide residues in food (Brown et al., 2022). These concerns were further underscored by qualitative investigations highlighting participants' concerns about the potential impacts of PFAS exposure on their children's health (Banwell et al., 2020; Wickham and Shriver, 2021), including an increased risk of disease development, particularly cancer (Banwell et al., 2020). Interestingly, some women were found to be more concerned about the health of their children and future generations than their own exposure to EDCs (Kelly et al., 2020). Finally, pesticide risk perception educational interventions—strategies or programs designed to enhance individuals' understanding and awareness of the risks associated with specific hazards—were more effective in households with older or female children. This effectiveness was reflected in changes in parents' risk perceptions and reported behaviors, as measured by pre- and post-intervention surveys (Muñoz-Quezada et al., 2019).

### 3.5. Cognitive factors

#### 3.5.1. Knowledge, awareness, and familiarity with EDCs

Our findings indicate that an individual's knowledge, awareness, and familiarity with EDCs are associated with a higher EDC risk perception. This is true for EDCs as a general category, as well as for specific EDCs. For example, Rouillon et al. (2018) found knowledge to be positively related to the risk perception of EDCs in general. Similarly, more knowledge about pesticides increased the likelihood of a respondent being concerned about them (Knight and Warland, 2005). It has also been shown that educational interventions can significantly increase EDC risk perceptions (El Ouazzani et al., 2022). Interestingly, in certain contexts, the lack of knowledge was associated with an increased concern about EDCs. For example, not knowing the legally permitted maximum residue levels for pesticides was linked to higher levels of concern about pesticide residues in food (Koch et al., 2017). Additionally, greater awareness of EDC risks was associated with increased risk perceptions. Specifically, individuals exposed to BPA risk narratives via media outlets were not only more likely to believe in the personal relevance of BPA risks (Viscusi et al., 2020), but also expressed increased concerns regarding BPA (P. R. Brewer and Ley, 2011).

When examining familiarity with pesticides gained through first-hand use, it was found that pesticide use was positively related to perceptions of their safety. Such individuals often held beliefs minimizing pesticide toxicity (Grieshop and Stiles, 1989). In contrast, non-users of pesticides tended to perceive increased risks from pesticides, both for themselves (Hirsch and Baxter, 2009; Nieuwenhuijsen et al., 2005), and the wider population (Nieuwenhuijsen et al., 2005). Furthermore, both amateur and professional pesticide users frequently perceived the potential benefits of pesticides as outweighing their risks (Grieshop and Stiles, 1989; Nieuwenhuijsen et al., 2005; Simoglou and Roditakis, 2022).

### 3.6. Psychosocial factors

#### 3.6.1. Trust in social institutions and worldviews

Studies have shown that trust in social institutions plays a crucial role in shaping EDC risk perception. For instance, qualitative studies showed that individuals generally expect the government to ban substances that pose significant health risks (Jansen et al., 2020b; Kelly et al., 2020). Trust in regulatory institutions was identified as a significant factor in determining pesticide risk perception. Specifically, Saba and Messina (2003) found that trust in the institutions regulating pesticide use accounted for 47% of the variance in pesticide risk perception and 25% in benefit perceptions. Another study discovered that people who had less trust in the food system were more likely to be concerned about pesticides (Knight and Warland, 2005) Additionally, lower trust index scores, which reflect consumers' trust in regulatory agencies and their confidence in food safety, were associated with higher perceived risks from the consumption and production of conventionally grown produce (Williams and Hammitt, 2001). Furthermore, a link was identified between trust in regulatory institutions and pesticide risk-benefit perceptions. Individuals who believed the benefits of pesticides surpassed their risks expressed greater confidence in the safety of plant-based foods and their certification processes. Conversely, those skeptical of this notion displayed lower confidence in the safety of such foods (Simoglou and Roditakis, 2022).

EDC risk perception was also associated with trust in science. For example, individuals with more positive attitudes toward science were less likely to be concerned about pesticides (Knight and Warland, 2005). However, a study focusing on mothers' PFAS risk perception observed a contrasting trend: those who had a higher level of trust in scientific institutions and social media believed that PFAS posed a greater health risk (Girardi et al., 2022). Yet, mothers with a stronger trust in political institutions perceived fewer risks associated with PFAS (Girardi et al., 2022). Political inclinations also seemed to influence EDC risk perception. For instance, voting for the conservative party was predictive of lower perceived pesticide risks (Dosman et al., 2001). Koch et al. (2017) and Saba and Messina (2003) showed that identifying oneself as an organic or conventional consumer was linked to specific pesticide risk perceptions and the perceived risks and benefits of pesticides. More specifically, organic consumers were more likely to believe that pesticide risks outweigh their benefits and were more concerned about pesticide residues in foods than conventional consumers. Lastly, interpersonal relationships, particularly with friends and family, emerged as an influential factor in shaping EDC risk perception. Specifically, individuals who relied on family or friends for food safety information were less likely to perceive high risks related to pesticide-related hazards (Williams and Hammitt, 2001). However, for PFAS, a wider social network was associated with a higher perceived risk associated with PFAS exposure (Girardi et al., 2022).

#### 3.6.2. Health-related concerns

Qualitative data from Kelly et al. (2020) shows that all participants viewed EDCs as a health threat. However, those with pre-existing medical conditions were particularly concerned about EDC risks. Similarly, Banwell et al. (2020) show that individuals who perceived their own health as poor believed they were at a greater risk from PFAS exposure. Finally, according to another study more than 80% were concerned about their physical health, and slightly more than a half about mental health as a result of living in a PFAS-contaminated areas (Lazarevic et al., 2023).

## 4. Discussion

This systematic review synthesized existing research on perceived health risks associated with endocrine-disrupting chemicals (EDCs). EDCs are compounds found in various everyday products that can negatively affect hormone functions in the human body. Following the PRISMA 2020 checklist (Page et al., 2021), we identified 45 studies on this topic.

Over the past 40 years, research on how people perceive the health risks of EDCs has expanded. Initially, most studies focused on pesticides, but since 2010, the scope has broadened to include other EDCs like BPA, PFAS, and phthalates. This shift aligns with evolving scientific understanding of diverse EDCs and their potential health risks (Diamanti-Kandarakis et al., 2009; Gore et al., 2015), alongside increased public awareness of these chemicals in their daily life (Jørgensen, 2019; Kjeldgaard Kristensen, 2021). Geographically, esearch was predominantly US-centric until the late 1990s, with a gradual shift towards Europe and other regions in subsequent decades, reflecting the global recognition of the issue (World Health Organization, 2012).

In the following sections, we discuss the influence of four key factors — sociodemographic factors, family-related factors, cognitive factors, and psychosocial factors — on the perception of EDC risks. We also address methodological considerations, limitations, policy implications, and future research directions.

### 4.1. Synthesis of findings

We identified four categories of factors influencing EDC risk perception: sociodemographic factors (age, gender, race, education, income, occupation, and residence), family-related factors (presence of children), cognitive factors (knowledge, awareness, and familiarity), and psychosocial factors (trust in institutions, worldview, and health concerns). This underscores the multifaceted nature of EDC risk perception.

#### 4.1.1. Sociodemographic factors

Existing research suggests that age is an important factor in the perception of EDC risks, with older adults generally showing greater concern, possibly due to a more cautious approach to health risks with age (Bonem et al., 2015). Gender is another key factor, with women generally showing greater concern about EDC health risks compared to men. This trend aligns with broader patterns in health risk perception (Alsharawy et al., 2021; Garfin et al., 2021) and risk perception in general (Gustafsod, 1998).

Race also influences EDC risk perception, though it has received limited attention, with studies focusing mainly on pesticides. Evidence suggests that non-whites perceive higher health risks associated with EDCs. This aligns with previous research showing that race remains a strong independent predictor of perceived risk, even when controlling for socioeconomic status (Macias, 2016).

The relationship between education level and EDC risk perception is complex and varies by type of EDC. Individuals with higher education levels show higher risk perception for some EDCs (e.g., BPA) and lower for others (e.g., pesticides). This pattern reflects broader trends in health risk perception literature. For example, higher education is associated with lower risk perception for certain hazards like influenza (Commodari, 2017) but higher for others like COVID-19 during its early stages (Wise et al., 2020).

Interestingly, no differences in risk perception by education level were found as the pandemic progressed (Wang et al., 2022). The mixed results may be due to more educated individuals having greater knowledge about pesticides than BPA, leading to lower risk perception for pesticides. Previous research has shown a positive correlation between education and knowledge of toxicology, and a negative correlation between knowledge and chemical risk perception (Bearth et al., 2019).

Income level appears to influence perceptions of EDC health risks, with higher-income individuals generally perceiving lower risks, based on studies on pesticides. This may be because higher incomes allow for preventive measures, such as buying organic produce, reducing perceived risk. Supporting this, research shows a positive correlation

between household income and the likelihood of purchasing organic food (Dimitri and Dettmann, 2012). Additionally, cost is a major barrier to choosing organic food, reinforcing the idea that higher income leads to behaviors that reduce perceived pesticide risks (Aschemann-Witzel and Zielke, 2017). This aligns with the risk reappraisal hypothesis, where protection behaviors reduce perceived risk (Kim et al., 2022).

Although based on a few studies, occupation appears to influence EDC risk perception, with effects varying by employment status and job type. Unemployed individuals tend to perceive higher EDC risks, consistent with findings that lower-income individuals also perceive higher risks. These results align with research showing a complex relationship between professional roles and the assessment of risks such as influenza, lead paint, antibiotics, and food preservatives (Hotle et al., 2020; Sjöberg et al., 2000).

Finally, geographic and residential context, particularly in studies on pesticides, was found to influence EDC risk perception. Factors like proximity to agricultural fields, population density, and urban or rural settings may shape individuals' experiences and perceptions of EDC risks. Although less studied than other sociodemographic factors within health risk perception literature, existing research highlights its significance. For example, health risk perceptions of hazards like extreme heat, lead paint, antibiotics, and food preservatives vary significantly by location, as shown in studies across different regions and countries (Howe et al., 2019; Sjöberg et al., 2000).

#### 4.1.2. Family-related factors

Research suggests increased concerns about EDC exposure in households with children, likely due to protective instincts and awareness of potential long-term health impacts on developing bodies (Kelly et al., 2020; Rouillon et al., 2017). This aligns with studies showing that the presence of children is associated with higher risk perceptions of various health hazards, such as nuclear disasters (Murakami et al., 2016), air pollution (Omanga et al., 2014), and genetically modified foods (Finucane and Holup, 2005).

#### 4.1.3. Cognitive factors

Knowledge and awareness of EDCs are related to risk perception, with increased knowledge often leading to heightened concerns. This aligns with research showing a strong correlation between knowledge and perceived risks when measured reliably and validly (Siegrist and Árvai, 2020).

Familiarity with EDCs presents a more complex relationship. For example, direct familiarity, such as among pesticide users, can sometimes lead to reduced risk perceptions (Grieshop and Stiles, 1989). However, experiencing adverse health effects after exposure significantly increases risk perception, suggesting that the absence of immediate effects may lead to a perception of safety. Similarly, recent personal experiences influence risk perceptions of influenza (Hotle et al., 2020), and individuals who have experienced food poisoning have higher risk perceptions of it (Parry et al., 2004).

#### 4.1.4. Psychosocial factors

Previous research identified various psycho-social factors influencing risk perception, such as trust, worldviews, psychological traits, and cross-cultural differences (Siegrist, 2021; Siegrist and Árvai, 2020). However, in our review, we identified only three such factors in connection with EDC risk perception, namely trust in social institutions, worldview, and health-related concerns.

Trust in social institutions plays a crucial role in shaping EDC risk perception. Generally, reduced trust in food systems, regulatory bodies, political institutions, and scientific entities is related to increased concerns about EDCs. This finding aligns with previous research showing that higher levels of trust in institutions are associated with lower perceived risks, especially when individuals have limited knowledge about a hazard and thus rely on trust as a heuristic to gauge its risks and benefits (Siegrist, 2021).

Worldviews, including political affiliations and consumer identities (e.g., organic consumers), were observed to influence EDC risk perception. Specifically, conservative political views are associated with lower perceived pesticide risks, while organic consumers show greater concerns. Additionally, interpersonal relationships also impact EDC risk perception. This aligns with recent findings that the relationship between worldviews and risk perception is complex and varies by risk type, context, and individual values (Siegrist and Árvai, 2020).

Finally, individuals with pre-existing medical conditions or general health concerns due to residing in contaminated areas exhibit heightened EDC risk concerns. This aligns with findings on increased risk perception following exposure to viruses or bacteria (Hotle et al., 2020; Parry et al., 2004) and COVID-19 risk perception (Bearth et al., 2021).

### 4.2. Methodological considerations

#### 4.2.1. Methods

EDC risk perception has been assessed using a variety of methods, including quantitative, qualitative, and mixed approaches. Only two intervention studies aimed at influencing EDC risk perception and changing exposure behavior were identified. This width of methods used to assess EDC risk perception contributes to a more comprehensive understanding of the topic. Qualitative studies identified key themes such as perceived severity, susceptibility, control, and concern (i.e., pre-existing health conditions and future generations), while quantitative studies quantified these themes and identified additional influencing factors. The intervention studies demonstrated how risk perception relates to actual behavior. However, although there are more than a dozen intervention studies on changing EDC exposure behavior (see review by Park et al., 2022), we included only two that evaluated risk perceptions while aiming to improve exposure behavior. The scarcity of such studies is surprising given the recognized link between individual risk perception and health-related behavior change (Ferrer and Klein, 2015).

Additionally, all intervention studies, whether focused on risk perception or not, were conducted within the health sciences domain and lacked a theoretical foundation in behavioral sciences—an approach inadequate for long-term behavior change.

#### 4.2.2. Sampling and participant characteristics

This review that research on EDC risk perception has covered a diverse range of populations. However, most studies focused on the general adult population, with only 15% using fully representative samples. While 50% of studies employed random sampling, generalizability may still be limited. There is a noticeable gap in understanding the risk perception of specific groups, such as pregnant women or parents of young children, despite the increased vulnerability of early life stages to EDCs (Gore et al., 2015).

Additionally, no studies examined adolescent risk perception, a critical gap given the importance of this developmental phase (Gore et al., 2015).

#### 4.2.3. Measurements

Quantitative research on EDC risk perception has primarily used ordinal scales, particularly Likert-type scales, with some studies employing bipolar scales (e.g., unsafe/safe, not harmful/very harmful). This variation in measurement warrants caution when comparing findings, as terminological differences can influence responses (Wolff et al., 2019). Additionally, none of the studies used the seminal psychometric paradigm to measure dimensions like controllability and dread (Fischhoff et al., 1978), potentially overlooking critical aspects of EDC risk perception.

Qualitative studies typically used interview or topic guides but did not specify how these guides were developed. In intervention studies, measurements included self-reported risk perception (ordinal scales) and biomarkers (i.e., changes in EDC levels in urine). This dual approach enhances understanding of the relationship between EDC risk

perception and behavior.

Most reviewed studies focused on the cognitive dimension of risk perception, consistent with the traditional focus on cognitive factors in decision-making theories (Loewenstein et al., 2001). Our results further show that most studies on cognitive and affective dimensions, or solely on affective dimensions, have been conducted recently, particularly after 2020 (see Table 1). Notably, none of the studies assessed the relative contributions of cognitive and affective dimensions, which could offer insights into the dominant factors shaping EDC risk perceptions.

This review also highlights the absence of a time-frame component in most studies, despite its importance in understanding EDC risks related to health (Patisaul and Adewale, 2009). Most studies measured risk perception at a single point in time. Given that different time orientations can influence perceptions of long-term health risks (Svenson, 1984), future research should conduct longitudinal studies to better understand changes in risk perception over time.

Finally, food and water are the most frequently examined contexts for EDC risk perceptions, likely due to the focus on pesticide exposure in most studies. However, given the multiple EDC exposures in daily life (Endocrine Society, n.d.-a), the literature lacks studies on more diverse sources.

#### 4.2.4. Quality assessment

This review included a quality assessment of the existing research, addressing methodological strengths and weaknesses. The average score for quantitative studies suggests acceptable quality, though generalizability remains an issue due to non-representative samples, a common challenge in social sciences (Zhao, 2021). The limited emphasis on providing details from pilot testing and discussing reliability and validity highlights the need for robust measurement tools and reporting practices. These are crucial for verifying the credibility and enabling comparisons across studies. However, transparency in describing methods and reporting all results is a positive aspect, aligning with the push towards open science (Munafò et al., 2017). The quality of qualitative and intervention studies was generally high, demonstrating good methodological rigor.

### 4.3. Limitations

This review has several limitations. First, despite our efforts, we may have overlooked some relevant studies. Our focus was primarily on English-language literature, and it is possible that by excluding studies in other languages, we may have missed some relevant findings. Second, our findings require cautious interpretation, comparison, and generalization, as many included studies used non-representative samples and diverse research methods. Additionally, the majority of included studies (27) focused on pesticide risk perception, potentially introducing bias since the EDC properties of pesticides were not emphasized to participants. Finally, although we took rigorous steps to minimize bias through independent coding, subtle influences from prior discussions between authors may have affected the coding process.

### 4.4. Policy implications

Our review identified five policy implications to enhance public awareness of EDC health risks. First, policymakers should launch targeted educational campaigns to fill knowledge gaps, informing the public about what EDCs are, where they are found, why they are harmful, and how to reduce exposure.

Second, since the lack of immediate health effects can reduce risk perception, communication strategies should highlight the negative health effects associated with EDCs to ensure the public remains aware of these effects, even if not immediately experienced.

Third, higher trust in social institutions is linked to lower EDC risk perceptions. In countries with high trust in regulatory institutions, these institutions should use this trust to inform the public about EDC risks and provide guidance on reducing exposure. Where trust is low, risk communication should come from the most credible source, as research shows that ideological alignment between the messenger and the audience significantly influences how the message is received (Turner, 2007).

Fourth, our findings show that interpersonal relationships and social networks significantly influence EDC risk perceptions, consistent with previous research (Pachur, 2024). Policymakers could enhance risk communication by organizing local workshops to foster dialogue about EDC risks and providing easily shareable educational materials to increase awareness.

Finally, risk communication could be more effective if personalized by demographics like age and gender. For example, women of childbearing age could be informed about potential fetal health effects, while parents and grandparents could learn about risks to young children. Activating the availability heuristic—where people estimate risk based on easily recalled examples—could enhance effectiveness (Tversky and Kahneman, 1974). Since firsthand EDC experiences are rare, highlighting indirect experiences, like in-utero exposure to diethylstilbestrol (linked to early-onset vaginal cancer), may be more impactful (Swan, 2001). Media coverage also plays a key role, as frequent reporting tends to increase perceived risk (Boholm, 1998).

### 4.5. Future research

This review highlights several promising areas for future research on EDC health risk perceptions. Several factors influencing these perceptions remain important but understudied, including geographic context within sociodemographic factors.

Understanding differences in EDC risk perception between countries with varying levels of awareness, as well as variations within a single country, is crucial. Future studies should also explore the underlying factors, such as socioeconomic status and education level, that may contribute to these geographical differences.

Furthermore, building on previous research (Siegrist and Árvai, 2020), future studies should examine the impact of psychosocial factors like psychological traits, cross-cultural differences, and cognitive biases on EDC risk perception. Additionally, exploring the heuristics individuals use when assessing EDC risks can offer valuable insights into the cognitive processes behind risk perception.

Given the evolving nature of EDC research and growing public awareness, future studies must expand beyond pesticide risk perception to include a broader range of EDCs, such as BPA, parabens, PFAS, and phthalates, for a more comprehensive understanding of risk perceptions. To reduce biases, future studies on pesticide risk perception should clearly inform participants that pesticides are categorized as EDCs, ensuring accurate risk assessment. Additionally, research should explore the perception of EDC mixtures, as this better reflects real-world exposure where multiple EDCs are encountered simultaneously.

Future research should also investigate differences in EDC health risk perceptions between experts and the general public. Comparing how environmental scientists, epidemiologists, pharmacologists, and public health researchers perceive risks compared to the general public can shed light on the potential gaps in understanding and the influence of specialized knowledge on risk perception.

Finally, future research would benefit from more representative sampling strategies to improve the generalizability of results, as well as samples from particularly vulnerable groups (e.g., pregnant women, parents of young children, and adolescents). Studies should also explore both cognitive and affective dimensions of EDC risk perceptions, quantifying each dimension's contribution. Furthermore, incorporating a time-frame component in study design and examining a broader range of EDC sources in relation to risk perceptions is needed. The use of standardized measurement tools, such as a dedicated EDC risk perception scale, could enhance precision and comparability, facilitating cross-

context comparisons and advancing our understanding across diverse populations and settings.

### 4.6. Conclusion

This review synthesized research on perceived health risks associated with endocrine-disrupting chemicals (EDCs) and identified key factors influencing EDC risk perception, including sociodemographic factors, family-related factors, cognitive factors, and psychosocial factors. The studies predominantly used quantitative methods, though measurement tools and sampling strategies varied widely. Limitations include challenges with generalization due to non-representative sampling and a focus on pesticides, without considering their EDC properties. Future research should explore EDC risk perceptions more broadly, prioritize representative samples, and assess a wider range of psychosocial factors. Longitudinal, cross-cultural, and geographically comparative studies are also needed. Policymakers should develop targeted educational campaigns, emphasizing the potential health effects of EDCs and tailoring messages to specific demographics.

### 4.7. Declaration of generative AI in scientific writing

During the preparation of this work, AP used "Elicit: The AI Research Assistant" (https://elicit.com/) in order to ensure that the extracted data contained no factual errors. The following information was assessed: year of the study, sample size, and country of the study. After using this tool, AP reviewed and edited the content as needed and takes full responsibility for the content of the publication.

## CRediT authorship contribution statement

**Aleksandr Pravednikov:** Writing – review & editing, Writing – original draft, Visualization, Methodology, Formal analysis, Data curation. **Sonja Perkovic:** Writing – review & editing, Writing – original draft, Supervision, Project administration, Methodology, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Carl-Johan Lagerkvist:** Writing – review & editing, Supervision, Methodology, Funding acquisition.

## Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Sonja Perkovic reports financial support was provided by Independent Research Fund Denmark (grant number: 2099-00015A). Carl-Johan Lagerkvist reports financial support was provided by Swedish University of Agricultural Sciences. Aleksandr Pravednikov declares no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Data availability

We have not included any primary data. For a detailed overview of the included studies, all extracted data, and research materials, we refer the reader to the OSF project page.

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