How to reduce fear, risk, and uncertainty in scientific knowledge? Risk communication of endocrine-disrupting chemicals: surveying the general public perceptions and knowledge

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Method Article

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Abstract

Endocrine-disrupting chemicals (EDCs) pose a threat to both human health and environment. Since the exact definitions and management systems of EDCs differ between countries and organizations, it is necessary to establish a system for evaluating the basic information and disseminating it appropriately. This study aimed to assess the risk communication of EDCs among the Korean public through a nationwide survey of their perceptions and general knowledge regarding the topic.

The survey was conducted on 2000 Korean individuals, including vulnerable populations. The questionnaire included questions on quality of life, general awareness, risk perception, exposure awareness, and health.

The findings revealed that the general public had poor awareness of the main components of EDCs and the risks associated with exposure to EDCs. In relation to EDCs, the public's perceptions of risks were influenced by certain variables such as dangerousness, spontaneity, controllability, fear, familiarity, scientific knowledge, and personal knowledge.

Based on these results, this study revealed that it is necessary to establish a harmonized management system for effective risk communication of EDCs.

Introduction

Endocrine-disrupting chemicals (EDCs) are known to deteriorate ecosystems, and they are linked to human reproductive dysfunctions, malformations, growth disorders, and cancer. Additionally, EDCs lead to ozone depletion and global warming, ultimately posing a threat to human and animal survival; thus, they are regarded as a major environmental problem (Bergman et al. 2012). Unlike hormones, EDCs do not decompose easily, and they are even more threatening when they accumulate in living bodies. The development of dispensable chemicals that are widely used in household items has made it difficult to prevent EDC bioaccumulation (Thomas et al. 2001). EDCs can enter the human body through contaminated air, soil, or water; therefore, unless efforts are made to ensure their eco-friendly production, manufacturing, technology, and environmental preservation, it will be increasingly difficult to prevent the influx of these substances. EDCs are known to act *in vivo* in humans and animals; they reduce the sperm count and induce female sex characteristics in males and inhibit the functions of growth hormones. EDCs comprise a wide range of synthetic chemicals, pharmaceuticals, and certain natural substances. Trace amounts of EDCs can influence reproductive functions because they affect the delicate endocrine system *in vivo*. Unlike acute and chronic toxicities, the effects of EDCs can also affect the next generation (Ankley et al. 1997; Kavlock et al. 1996).

EDCs can cause various hormonal problems in both fetuses and children, who are more vulnerable to EDCs than the general population. For instance, EDCs can cause memory and learning disorders, attention deficit and hyperactivity disorders, hearing loss, failure to form myelin sheaths that surround the brain's nerve cells, lack of sophisticated motor skills, loss of balance, underdevelopment, motor disorders

(such as cerebral palsy, seizures, and hydrocephalus), mental retardation, and other permanent damages to the nervous system. These effects vary depending on the timing of intake and genetic factors (Colborn et al. 1996). There is a growing concern regarding EDCs owing to their toxicology, and an increasing number of studies have reiterated their harmful effects on the human body (Longnecker et al. 2003).

To avoid the harmful effects of EDCs on the human body, it is important to elicit awareness of the environmental disorders caused due to these substances and promote environmentally friendly lifestyle changes while influencing people's culture, attitudes, and perceptions through health education. Special attention must be given to both children and women of childbearing age who are relatively more vulnerable to EDCs. Thus, it is essential to develop self-management capabilities for health by educating children and women on the countermeasures for environmental diseases caused due to EDCs. Promoting eco-friendly lifestyles can also help reduce prenatal exposure to EDCs, which can be achieved by providing accurate information on the nature and effects of EDCs on women of childbearing age.

This study aimed to assess the risk communication of EDCs among the general public by conducting a survey on public perceptions and general knowledge regarding the topic. The findings can help establish an efficient management system for risk communication to reduce the effects of EDCs. The public perception of the risks of EDCs was defined as their perceived severity at different stages of infant development and perceived susceptibility to EDC exposure. The determinants reported in the qualitative study were age, strong maternal figure, socio-professional category, knowledge level, and involuntary nature of exposure. Certain studies have estimated the risk perceptions of pregnant women on exposure to EDCs and evaluated their determinants. A qualitative study based on the health belief model has been conducted by interviewing pregnant women and a focus group of perinatal and environmental health and prevention professionals in 2015 in the city of Poitiers, France (Rouillon et al. 2018). Age, strong maternal figure, socio-professional category, knowledge level, and involuntary nature of exposure are the determinants reported in this qualitative study. The mean score of EDC risk perception was reported to be 55.0 ± 18.3 out of 100 points. In this study, we confirmed age and knowledge level as determinants using a statistical model. Further, a study was conducted in the French Department of Vienne between 2014 and 2016, comprising semi-structured interviews with pregnant women and a focus group of professionals in perinatology and environmental health. A psychosocial questionnaire comprising the scores of 300 pregnant and postpartum women was administered to participants (Rouillon et al. 2017). The mean score of their knowledge was 42.9 ± 9.8% (from 13.5 to 75.7%). Their attitude towards exposure was determined based on risk perception. The mean level of cues to action to reduce EDC exposure was estimated to be 56.9 ± 22.5% (from 0 to 100). The overall level of risk perception regarding the contraction of diseases in wetlands is high. Exposure to water-related infectious diseases is driven by physical contact of the user with water in wetlands, pathogen characteristics, and disease vectors in both domestic and occupational environments (Anthonj et al. 2019). The knowledge and attitude of the Italian public towards environmental risks as possible determinants of diseases were assessed using previous studies (Bianco et al. 2008). We observed that 98.4% of the surveyed individuals were aware that smoking tobacco is a risk factor for respiratory diseases, and among these, 4.0% were aware that there is no evidence indicating an increased risk of childhood leukemia in people living near mobile phone base

stations. Participants who were knowledgeable about the effects of an environmental risk factor were more likely to know about other risk factors. The findings of this survey would provide valuable information to researchers and policymakers regarding public awareness of environmental risks. These findings should be considered when implementing risk communication and protective actions.

Materials And Methods

Identification of the health effects of EDCs

The health impact of EDCs was investigated to determine the priorities for management of confirmed EDCs. Particularly, the reproductive and developmental toxicities of EDCs were examined, and carcinogenic substances were prioritized.

Carcinogenicity was determined based on the World Health Organization International Agency for Research on Cancer monographs; the Integrated Risk Information System United States Environmental Protection Agency (US EPA) Guidelines for Carcinogen Risk Assessment; the European Union (EU) Classification, Labeling, and Packaging (CLP; Annex I of Council Directive 67 / 548 / EEC was included in Annex VI of CLP Regulation (EC) No. 1272/2008). EPA pro. 65, Korea Occupational Safety and Health Agency (KOSHA), and the National Toxic Program. Using these sources, 54 out of 131 substances were reported to be potentially carcinogenic or were classified as carcinogenic substances for animals and humans.

Mutagenicity was determined based on US EPA, EU CLP, and KOSHA Globally Harmonized System of Classification and Labelling of Chemicals classifications, and 12 out of 131 substances were confirmed as mutagens (Fig. 1).

Of the 131 EDCs managed and used in Korea, 42 were included in the EU priority list of EDCs. Of these 42 substances, 24 were carcinogens and 17 had reproductive or developmental toxicity. Among the non-carcinogens, five had reproductive or developmental toxicity. Substances with both carcinogenicity and reproductive or developmental toxicity were classified as first priority, substances with only reproductive or developmental toxicity were classified as second priority, and substances with carcinogenicity only were classified as third priority.

Characteristics of study participants

An online nationwide survey of 2000 Korean individuals was conducted. The online survey used a structured questionnaire that was administered to participants between 15 and 59 years of age. A total of 1,026 men and 974 women were included in the survey. Subjects were selected to represent most of the regions in Korea, and they were extracted according to gender and age. Among women, 155 were mothers of children aged 0–5 years, 240 were mothers of children aged 6–14 years, and 435 were women of childbearing age. The subgroups were investigated to understand their vulnerability to EDCs. Tables 1 and 2 list the characteristics of participants and specific vulnerable groups, respectively.

Table 1
Characteristics of samples

Region	Sex	Age (years)					Subtotal	Total
		15–18	**19–29**	**30–39**	**40–49**	**50–59**		
Seoul	M	13	45	48	49	44	199	**400**
	W	12	45	48	49	47	201	
Incheon/Gyeonggi	M	24	67	71	82	72	316	**618**
	W	22	62	69	80	69	302	
Daejeon/Chungcheong	M	8	23	23	27	26	107	**205**
	W	7	20	22	25	24	98	
Gwangiu/Jeonla	M	9	22	20	25	24	100	**191**
	W	9	19	18	23	22	91	
Daegu/Gyeongbuk	M	8	22	21	25	25	101	**196**
	W	7	18	20	25	25	95	
Busan/Ulsan/Gyeongnam	M	12	35	34	39	39	159	**308**
	W	11	29	32	38	39	149	
Kangwon/Jeju	M	3	10	9	11	11	44	**82**
	W	3	7	7	10	11	38	
Total	**M**	**77**	**224**	**226**	**258**	**241**	**1,026**	**2,000**
	W	**71**	**200**	**216**	**250**	**237**	**974**	
	Sub	**148**	**424**	**442**	**508**	**478**	**2,000**	**2,000**
M: men; W: women								

Table 2
Characteristics of vulnerable groups

Group	**Number**
Married fertile women aged 20–49 years	435
Mothers raising infants aged 0–5 years	155
Mothers raising school children aged 6–14 years	240
Total	**830**

An online survey was conducted on a panel available from a survey agency to examine the awareness of EDCs among the Korean public. A 2000-person sample was used with proportional sex, age, and regions; this included major EDC-vulnerable groups, namely fertile women aged 20–49 years, infants, young children (0–5 years), and school-aged children (6–14 years). However, as it was practically impossible to survey children aged 14 years or below without parental consent, mothers of children aged 14 years or below were included in the survey. To stratify the sample, proportional allocation was performed in terms of sex, age, and region. A preliminary survey to check the validity of the questionnaire and survey system was conducted in November 2015, and the main survey was conducted between January 13 and January 19, 2016. The survey was conducted from January 19 to February 10, 2016.

Main indicators of the perception survey

The participants' level of knowledge of the physicochemical properties, sources, and health effects of EDCs was investigated along with their awareness of the main components of EDCs, their recognition of products that mainly contain EDCs, and their perceptions of the harmful effects of EDCs on humans. Other indicators of the survey included a comparison of mortality rates and awareness of health risks.

The main objectives of the survey were to develop a tailored risk communication strategy for EDCs and to establish a management system for risk communication. As the questionnaire was not intended to evaluate knowledge, there were no right or wrong answers, and the respondents were encouraged to be honest with their answers.

The survey comprised four steps. First, a research plan was established, and the questionnaire and sample design were confirmed. Next, the questionnaire was built and tested on a web page, following which a pretest was performed with an online survey. Finally, the data were processed, and results were validated (Fig. 2).

Composition of the questionnaire

The questionnaire comprised six parts, 45 questions on the quality of life, 14 questions on general EDC awareness, 10 questions on risk perceptions of EDCs, 4 questions on awareness of exposure to EDCs, 6 questions on respondents' health, and 5 questions on respondents' characteristics. Table 3 lists the content of each survey component.

Table 3
Composition of the EDC perception survey

Survey part	Description of items
Selected questions	General information
Quality of life	General physical health condition
General perceptions of EDCs	General perception and risk perceptions of smoking, particulate matter, and traffic accidents
Risk perceptions of EDCs	Health effects, EDC-related variables, route of exposure, and risk information
Perceptions of EDC exposure	Products containing EDCs
Respondents' health conditions	History of diseases and smoking status
Respondents' characteristics	Marital status, educational attainment, occupation, and family outcomes

The section on general awareness of EDCs (environmental hormones) comprised items regarding the respondents' interests in environmental hormones and prior knowledge and awareness of environmental hormones. The section on awareness of EDC risks comprised items regarding the reliability of information about environmental hormones obtained using different types of media, including internet news articles, blogs/social media, newspapers, and street campaigns. The section on perception of EDC exposure comprised items regarding products that are believed to contain bisphenol A, phthalate, polychlorinated biphenyl, and benzopyrene. The study surveyed the respondents' awareness of EDC exposure, their perceptions of the products containing specific environmental hormones, and their lists of the top three products containing environmental hormones. The perceived EDC exposure rankings were then determined based on this information.

The component on the risk perception of EDCs comprised risk variables ranked in the order of "dangerousness", "spontaneity", "controllability", "fear", "familiarity", "scientific knowledge", and "personal knowledge". Regression analysis was performed on the survey results to confirm the respondents' levels of awareness and risk perception of EDCs. Further measures were devised to utilize these perceptions.

The following measurement variables were applied in the section on perceptions of EDC risks (EDCs/environmental hormones):

* Dangerousness: How dangerous are EDCs to the human body?

* Spontaneity: Are respondents aware that certain products or foods contain EDCs but use them nevertheless?

* Controllability: ability to control the effects of EDCs on the human body.

* Fear: degree of fear of EDCs.

* Familiarity: degree of infiltration of EDCs in the respondents' surroundings that can harm the human body.

* Scientific knowledge: degree of dissemination of scientific knowledge about EDCs to people around oneself.

* Personal knowledge: degree of one's own knowledge of EDCs.

Statistical analysis

Statistical analyses were performed using the IBM SPSS 20 package. Intergroup comparisons of the questionnaire about awareness were performed using t-tests and analysis of variance, and the significance among predictors was analyzed using Pearson correlation tests.

This study aimed to identify the predictors of EDC awareness among the public to examine information about their responses to risk communication. The independent variables that predicted various levels of awareness were identified using multiple regression analysis. Significance was set at $p < 0.05$, with values of < 0.1 considered to represent tendencies.

Results And Discussion

General perceptions of EDCs

The first part of the survey asked the following question: "Have you ever heard of EDCs?" This was followed by the question: "If you know about EDCs, what do you think are their main components?" The respondents were instructed to select any one or more of the following choices: benzene, bisphenol A, phthalate, high-density polyethylene, or others (Fig. 3).

Most participants thought benzene was the main component of EDCs; however, although benzene is a primary carcinogen, it is not the main component of EDCs. This result indicates that the participants' general knowledge and perceptions of EDCs were incorrect.

Risk perceptions of EDCs

The second part of the survey was constructed to understand the respondents' risk perceptions of EDCs. Table 4 lists the results of the risk perception variables assessed in this study. The general public's risk perceptions of EDCs were the highest in terms of "dangerousness"; however, they were relatively low in terms of "scientific knowledge" and "personal knowledge." The second highest among the seven risk perception factors was "fear," suggesting that citizens experience a significant amount of fear of EDCs.

Table 4
Items of risk perception variables in the survey questionnaire

Risk perception variables	Descriptions of items	Scale endpoints	
		Low (1)	High (7)
Dangerousness	Do you think that EDCs have dangerous effects on the human body?	5.47	
Spontaneity	Do you ever reluctantly use products containing EDCs?	3.81	
Controllability	Do you think that risk and damage of EDCs can be controlled (decreased) to some extent by your own effort or attention?	4.01	
Fear	Do you worry about the danger of EDCs to some extent?	4.63	
Familiarity	Do you think about how easily the risks and dangers of EDCs can occur in your vicinity?	4.50	
Scientific Knowledge	How much knowledge about EDCs do you think people have?	3.53	
Personal Knowledge	How much do you know about the risks and dangers of environmental hormones?	3.86	

Regression analysis

Regression analysis was conducted using “dangerousness”, “spontaneity”, “controllability”, “fear”, “familiarity”, “scientific knowledge”, and “personal knowledge” as dependent variables for each independent variable, such as sex, age, educational attainment, and exposure to EDCs. The results are listed in Table 5.

Table 5
Regression analysis of the variables of EDC perception survey

Dependent variable	Independent variable		
Dangerousness	Sex	Age	Educational attainment
Spontaneity	Family outcomes	General health condition	Physical health condition
Controllability	Physiological health condition	Quality of life	Information
Fear	Exposure condition	Information	Information about bisphenol-A by media
Familiarity	Information about phthalate by media	Contact degree by institution	Contact degree by media
Scientific Knowledge	Contact degree by meeting	Reliability degree by institution	Reliability degree by media
Personal Knowledge	Reliability of information by meeting	Risk information by institution	Risk information by media
	Risk information by meeting	Promotional material by media	

Table 6 lists the results of regression analysis, the risk perception variable, and each independent variable for “fear.” The affecting variables included “age”, “physical health condition”, “mental health condition”, “interest”, “exposure condition”, “information about bisphenol-A from the media”, “information about phthalate from the media”, “contact degree by meeting”, and “promotional material from media”.

Table 6
Regression analysis of the variable “fear” among the seven risk perception variables

Model	Unstandardized coefficients		Standardized coefficients	t	Significance
	B	SE	Beta		
(Constant)	0.664	0.489		1.358	0.175
Sex	0.039	0.052	0.016	0.761	0.447
Age	0.013	0.002	0.132	5.687	0.000
Educational attainment	0.012	0.023	0.012	0.535	0.593
Family outcomes	0.015	0.016	0.019	0.921	0.357
General health condition	0.086	0.077	0.023	1.120	0.263
Physical health condition	−0.311	0.094	−0.071	−3.308	0.001
Physiological health condition	−0.186	0.062	−0.064	−3.007	0.003
Quality of life	0.026	0.072	0.008	0.362	0.717
Interest	0.391	0.042	0.210	9.303	0.000
Exposure condition	0.201	0.045	0.094	4.508	0.000
Information	0.090	0.054	0.035	1.657	0.098
Information about bisphenol-A by media	0.282	0.056	0.145	5.010	0.000
Information about phthalate by media	0.126	0.053	0.066	2.359	0.018
Contact degree by institution	0.005	0.029	0.005	0.166	0.869
Contact degree by media	0.038	0.039	0.031	0.977	0.329
Contact degree by meeting	0.080	0.026	0.092	3.130	0.002
Reliability degree by institution	−0.032	0.035	−0.029	−0.913	0.361
Reliability degree by media	−0.087	0.046	−0.070	−1.882	0.060

*B: beta coefficient, **SE: standard error

Model	Unstandardized coefficients		Standardized coefficients	t	Significance
	B	SE	Beta		
Reliability of information by meeting	0.024	0.028	0.026	0.871	0.384
Risk information by institution	0.016	0.033	0.015	0.480	0.631
Risk information by media	0.015	0.041	0.012	0.363	0.717
Risk information by meeting	−0.007	0.024	−0.009	−0.306	0.759
Promotional material by media	0.147	0.032	0.114	4.679	0.000
*B: beta coefficient, **SE: standard error					

Table 7 lists the variables that influenced the risk perception variables, such as “dangerousness”, “spontaneity”, “controllability”, “fear”, “familiarity”, “scientific knowledge”, and “personal knowledge”. “Personal knowledge” had the highest number of influencing variables (11 variables) followed by “spontaneity” (9 variables) and “fear” (9 variables).

Table 7
Variables that influenced the risk perception variables

Dependent variable	Influencing variables
Dangerousness	Sex (M), age (+), family outcome (+), quality of life (+), interest (+), exposure condition (+), information about bisphenol-A by media (+), and promotional material by media (+)
Spontaneity	Sex (W), age (−), general health condition (+), physical health condition (+), quality of life (−), interest (−), information (+), information about bisphenol-A by media (+), and contact degree by meeting (−)
Controllability	Sex (W), educational attainment (−), exposure condition (−), information about bisphenol-A by media (+), information about phthalate by media (+), and reliability degree by media (+)
Fear	Age (+), physiological health condition (-), physiological health condition (−), interest (+), exposure condition (+), information about bisphenol-A by media (+), information about phthalate by media (+), contact degree by meeting (+), and promotional material by media (+)
Familiarity	Exposure condition (+), information about bisphenol-A by media (+), information about phthalate by media (+), contact degree by institution (−), risk information by institution (+), and promotional material by media (+)
Scientific knowledge	Information (−), information about bisphenol-A by media (+), information about phthalate by media (+), contact degree by institution (+), contact degree by media (+), and promotional material by media (−)
Personal knowledge	Quality of life (+), interest (+), information (−), information about bisphenol-A by media (+), information about phthalate by media (+), contact degree by institution (+), contact degree by media (−), contact degree by meeting (−), reliability degree by media (−), reliability of information by meeting (+), and promotional material by media (−)

(+) indicates a positive effect, and (-) indicates a negative effect.

The above findings reflect the general public's knowledge and perception of EDCs. The data can serve as a basis for establishing various application methods to increase the knowledge of EDCs and to reduce the health effects of these substances. Moreover, these findings can help in developing appropriate strategies for policymaking, disseminating information via media, educational promotion, and target utilization.

Necessity of studying EDCs

EDCs are defined and managed slightly differently in each country and institution. Furthermore, the number of EDCs is increasing as research progresses owing to the development of new chemicals. Therefore, EDCs do not have a globally confirmed list. The Ministry of Environment in Korea has been monitoring research annually since 1999, based on 67 chemicals suggested by the World Wildlife Fund, which is referred by most countries. Meanwhile, the Hazardous Chemical Substances Control Act, Air Quality Conservation Act, Water Quality Conservation Act, Industrial Safety and Health Act, Dangerous

Goods Safety Management Act, Food Sanitation Act, Pharmacist Act, and Pesticide Management Act monitor 94 substances; however, only 14 of them are regulated. An increasing number of studies have investigated the effects of EDCs on humans, which are related to the role of the endocrine system in regulating the body; however, the underlying mechanisms remain unclear.

There are no criteria for regulating EDCs under current Korean laws, the risk assessment system is insufficient, and the methods for managing EDCs are limited. Further, there is controversy surrounding the criteria for EDCs and the finding that exposure to low levels of any chemical can affect the human endocrine system (Colborn et al. 1996). However, research has indicated that exposure to EDCs is associated with a gradual decrease in the age of one's first menstruation (Kaplowitz et al. 2001), a decrease in sperm count (Auger et al. 1995), a decrease in the male to female sex ratio at birth (Davis et al. 1998), an increase in the number of cases of hypospadias (Paulozzi 1999), and an increase in the number of cases of testicular cancer (McKiernan et al. 1999).

Conclusions

The precise definition and management systems for EDCs currently differ between countries and institutions. Therefore, it is necessary to establish a system to evaluate critical EDC information for accurate information dissemination. In this study, 2000 Korean individuals, including individuals who were more vulnerable to EDC exposure, participated in a perception survey. This study revealed that the general public had poor awareness of EDCs. In the survey, the participants considered benzene as the main component of EDCs, which was incorrect. The general public's risk perceptions of EDCs were influenced by variables such as "dangerousness", "spontaneity", "controllability", "fear", "familiarity", "scientific knowledge", and "personal knowledge". Therefore, strategies such as policymaking, media, educational promotion, and target utilization should be employed to establish a risk management system for EDCs for the general public with the aim of reducing exposure and preventing their adverse effects (Fig. 4).

To promote risk communication about the harmful nature of chemicals to the public, it is vital to understand the causes of various psychological hazards and to analyze the gaps between these psychological hazards (risk perception) and real risk. To this end, it is necessary to utilize the results of governmental policy promotions and industry-led delivery of information about chemicals.

Declarations

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Figures

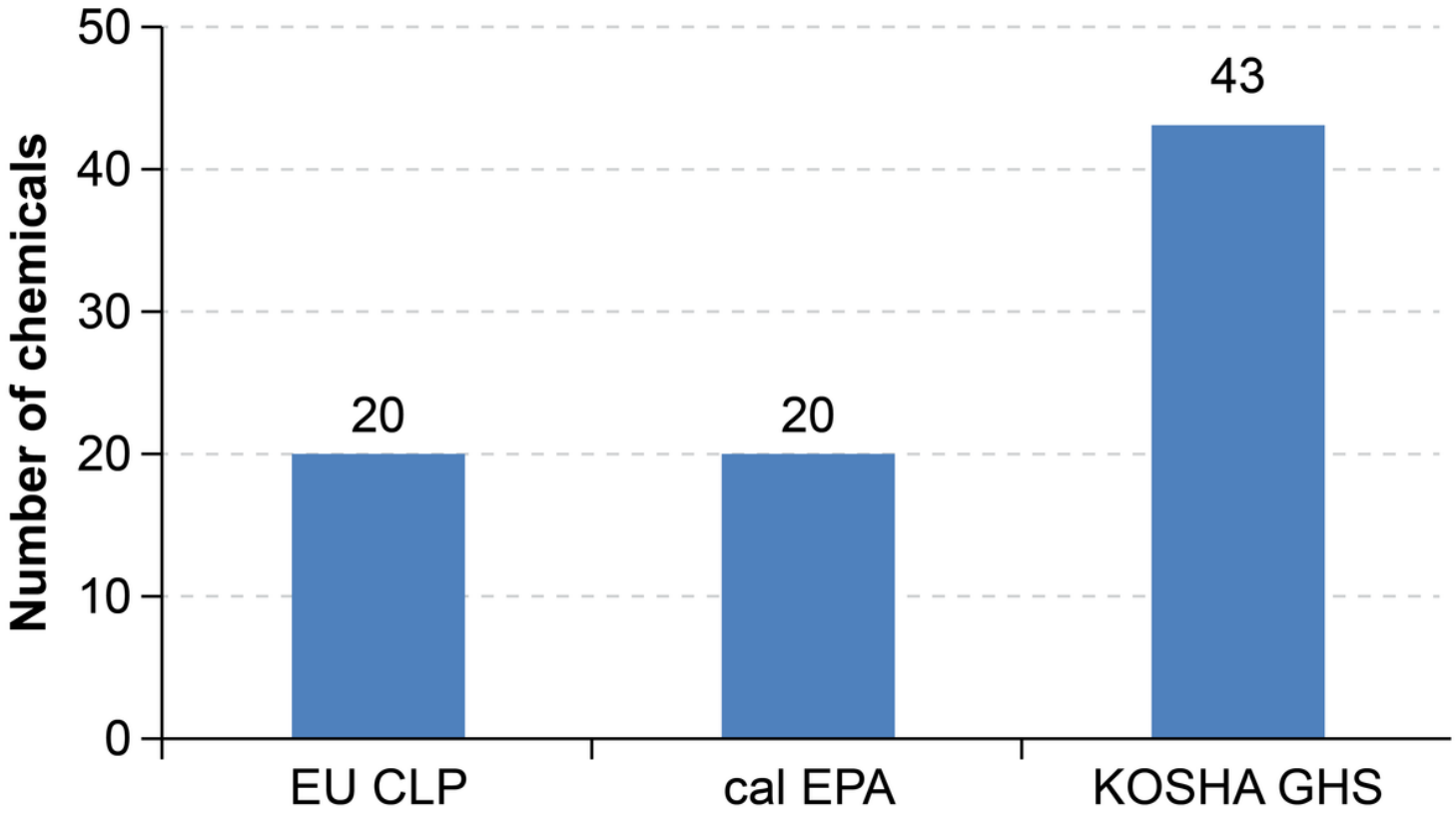

Figure 1

Reproductive Toxic Chemicals in Korea (KOSHA), EU, and US

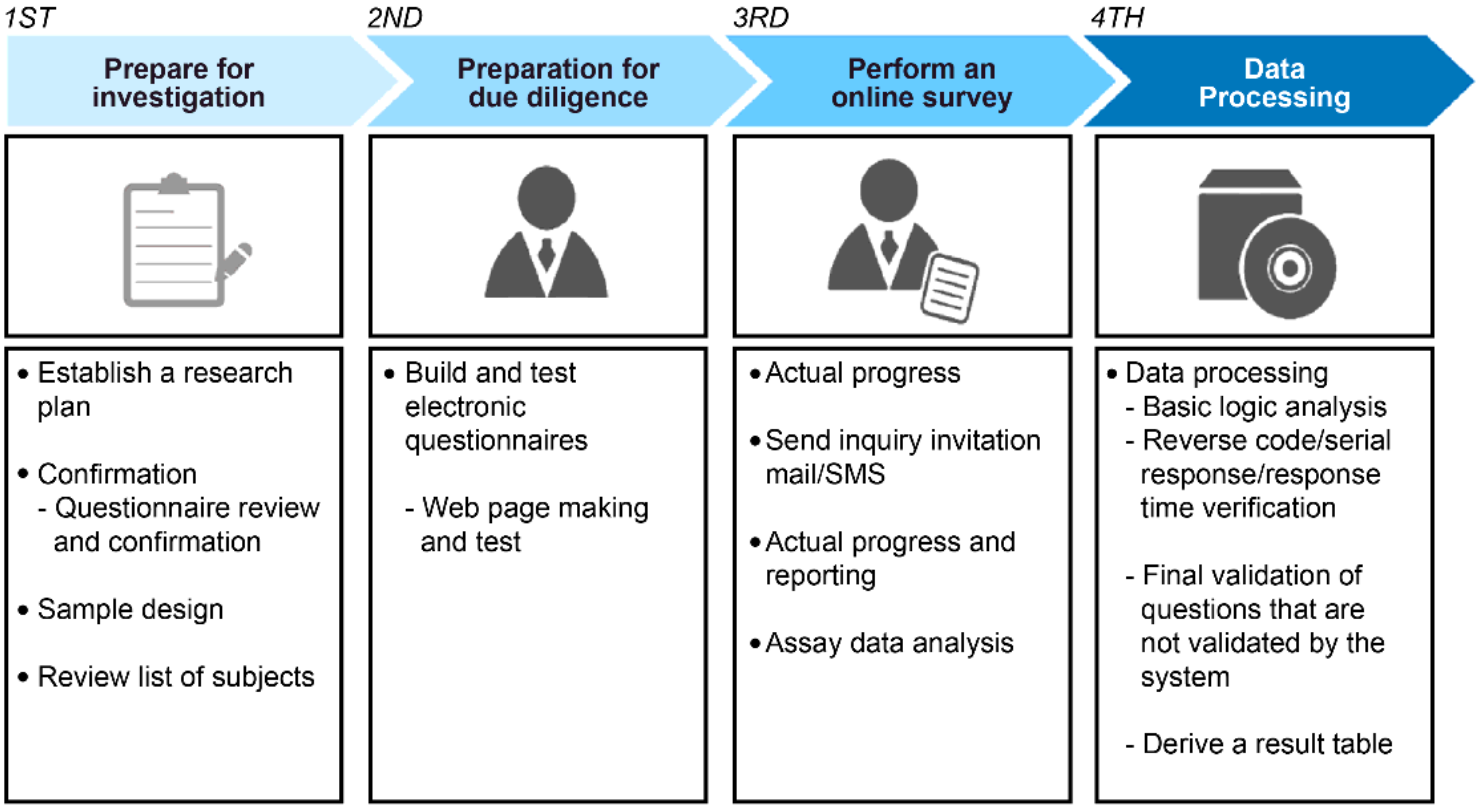

Figure 2

Online survey process for endocrine-disrupting chemicals

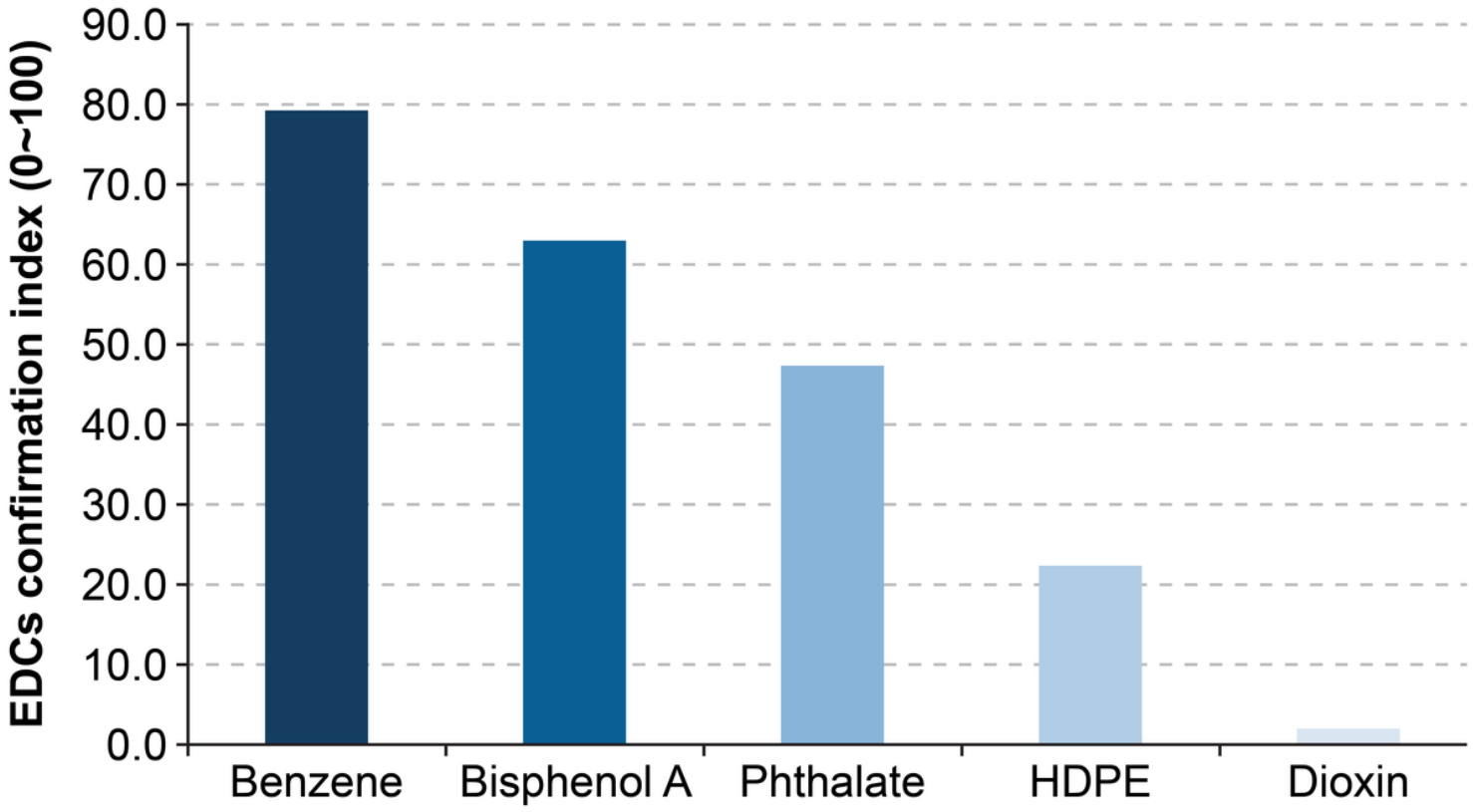

Figure 3

Respondents' perceptions regarding the main components of endocrine-disrupting chemicals (EDCs). HDPE: high-density polyethylene

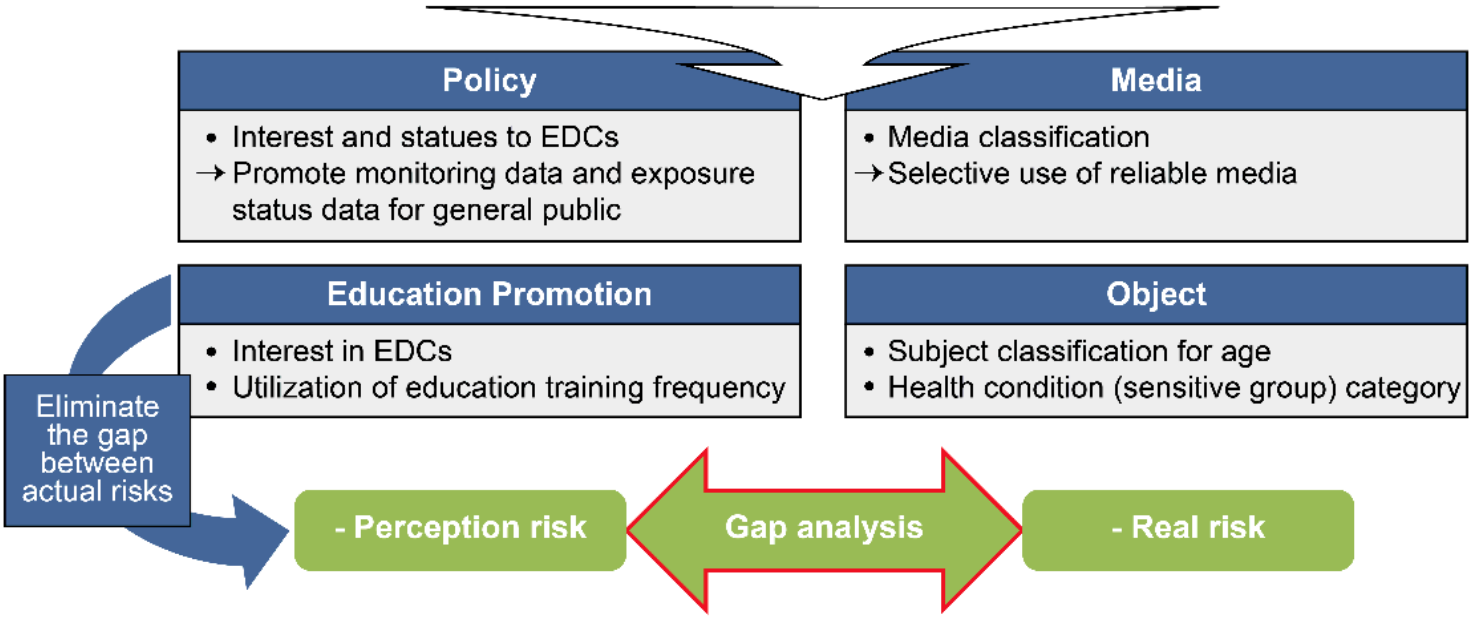

Figure 4

Risk communication strategy for EDCs