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Overview of the Development of the Korean Exposure Factors Handbook

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A set of exposure factors that reflects the characteristics of individual behavior capable of influencing exposure is essential for risk and exposure assessment. In 2007, the Korean Exposure Factors Handbook was, therefore, issued, driven by the need to develop reliable exposure factors representing the Korean population. The purpose of this study was to overview the development process of the Korean Exposure Factors Handbook and major recommended exposure values for the Korean population to allow information exchanges and comparison of recommended values among nations. The researchers reviewed the domestic data that could be used in the development of exposure factors, confirmed a knowledge gap, and set a priority of development by phases. A methodology to measure exposure factors was established to develop measuring techniques and test their validity. Data were processed or a survey was conducted according to the availability of data. The study thus produced recommended values for 24 exposure factors grouped by general exposure factors, food ingestion factors, and activity factors by setting up a database of exposure factors and carrying out statistical analysis. The study has significantly contributed to reducing the potential uncertainty of the risk and exposure assessment derived by the application of foreign data or research findings lacking representativeness or grounds by developing a set of exposure factors reflecting the characteristics of the Korean people. It will be necessary to conduct revisions in light of the changing statistical values of national data and the exposure factors based on Korean characteristics.

Key words: Risk assessment, Environmental exposure, Handbooks

INTRODUCTION

Human exposure assessment of environmental contaminants has been used as an important tool to establish environmental standards and public health policies [1]. It requires a set of exposure factors reflecting the human behavioral characteristics that can influence human exposure such as air, water, food, and soil intakes, and the period and frequency of exposure in addition to the concentration of contaminants in the air, water, food, and soil [2].

In 1989, the United States Environmental Protection Agency (US EPA) devised a set of exposure factors and issued its first exposure factors handbook that offered recommended values. It issued a revised version in 1997 and another one in 2011 [1]. Even though the Exposure Factors Handbook of the EPA contains a great deal of valuable information, its recommended values have a limited scope of application in other countries since they address the needs of the American people.

Not many nations, however, have so far succeeded in developing their own exposure factors handbooks since producing one involves a difficult development process. Canada issued

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one and offered recommended values in 1994 [3]; the European Commission Joint Research Centre started to develop a database called ExpoFacts, collecting data similar to those of EPA's Exposure Factors Handbook in 2002 [4]; the National Institute of Advanced Industrial Science and Technology of Japan published its Japanese version in 2007 [5]; and in recent years, China has been among the other countries implementing a national-level research project to set exposure factors and develop a handbook [6].

Korea took on a three-year research project called "Development of the Korean Exposure Factors Handbook" in 2005 and issued the Korean Exposure Factors Handbook based on the findings in 2007 [7]. Korea comes second to none other than the US in terms of the scope of content and issuance time of such a handbook. Once it was developed, the handbook has been cited and used in many domestic studies on exposure assessment [8-17].

Following several recent developments including the increasing awareness of a need to develop an exposure factors handbook fit for each nation and the actual progress of its development in some nations, a need has surfaced to exchange information about the development process and to compare recommended values of exposure factors among nations. The Korean Exposure Factors Handbook, however, is facing some limitations regarding international citation and utilization since it is written in Korean and has not been reported as a regular scientific paper. The Journal of Preventive Medicine and Public Health thus decided to present a special review in the current issue, introducing the development process of the handbook and the major recommended values.

The special review consists of a total four papers. The present paper serves as an introduction to the development process and significance of the handbook as well as an overview of its development. Its three sister papers describe the development process of the exposure factors in the areas of general exposure, food ingestion, and human activity along with recommended values in each of the areas. They are "General Factors of the Korean Exposure Factors Handbook," "Food Ingestion Factors of the Korean Exposure Factors Handbook," and "Activity Factors of the Korean Exposure Factors Handbook."

Since space is limited in the journal, the special review offers only the most representative recommended values of the exposure factors in the Korean Exposure Factors Handbook instead of them all. Those needing more specific recommended values can consult the Korean Exposure Factors Handbook. More recent data might have become available home and abroad after the development of the handbook, but the special review will consider the comparison of data at the time of its development when comparing the handbook data with those of its overseas counterparts since its main focus is to introduce the handbook.

DEVELOPMENT PROCESS

Brief History

In Korea, interest in and research on risk and exposure assessment became brisk in 2000. Researchers would adopt individual exposure factors needed for risk or exposure assessment at their own discretion or, in many cases, borrow the American exposure factors. As a result, exposure assessment results would vary among the researchers and lack certainty and reliability by using the exposure factors of a foreign country that did not reflect the exposure characteristics of Korea based on the population's ethnicity, environment, culture, and life habits [2]. The need was thus identified to develop a reliable set of exposure factors to represent the entire nation of Korea in order to ensure reliable risk assessment and establish all kinds of national criteria related to the environment.

The Korean Exposure Factors Handbook, a kind of pilot study conducted as part of the "Human Exposure Assessment for Total Risk Assessment of Environmental Contaminants" in 2001, was the nation's first study that noted the need for recommended values of exposure factors and explored the potential for their development [18]. The study reviewed the existing data available for the nation, concluded that there was a serious shortage of highly reliable nationally representative data, and proposed a full-blown study to generate recommended values of exposure factors at the national level. In addition, it offered provisional recommended values in use by the combination of some domestic data and the contents of the US EPA Exposure Factors Handbook.

Since then, a good number of national statistics were established with high reliability and representativeness under the leadership of various Koreans ministries, and the Core Environmental Technology Development Project for the Next Generation was launched to support basic environmental research. "Development and Application of Korean Exposure Factors" was one of the studies that benefited from its support. The Korean Exposure Factors Handbook was finally developed based on the results of the three-year study conducted between De-

cember 2004 and November 2007.

Development Process

Figure 1 shows the development process of the Korean Exposure Factors. The researchers reviewed the existing data and literature along with previous studies, confirmed a knowledge gap, and evaluated whether there were domestic data available for the development of exposure factors and identification of the reliability level of the data. They also set a host of criteria similar to the approach to examining the reliability of data in the US EPA Exposure Factors Handbook, evaluated them as high, medium, and low, and compiled the findings. In evaluating the reliability of the data, what was considered was verification of the data, reproducibility, association with exposure factors, connections with the population characteristics, primary data, recency, appropriateness of data collection period, size of the study, representativeness of the subjects, variability of the data, the research design, and reliability of measurement.

Of the exposure factors that were the top priority in the risk assessment, 24 exposure factors from the areas of general exposure, food ingestion, and activity factors were selected as the targets of research and development by taking into account whether there were reliable domestic data available or whether such data could be generated within a short period of time. Compared with their counterparts in the US EPA Exposure Factors Handbook, the items of general exposure factors were the same; to the food ingestion factors, however, were added the recommended values for the intakes of fats and oils, seaweeds, oilseeds and their products, seasonings, and sugars and sweeteners. Activity factors also had difference between Korea and the US in the items of factors.

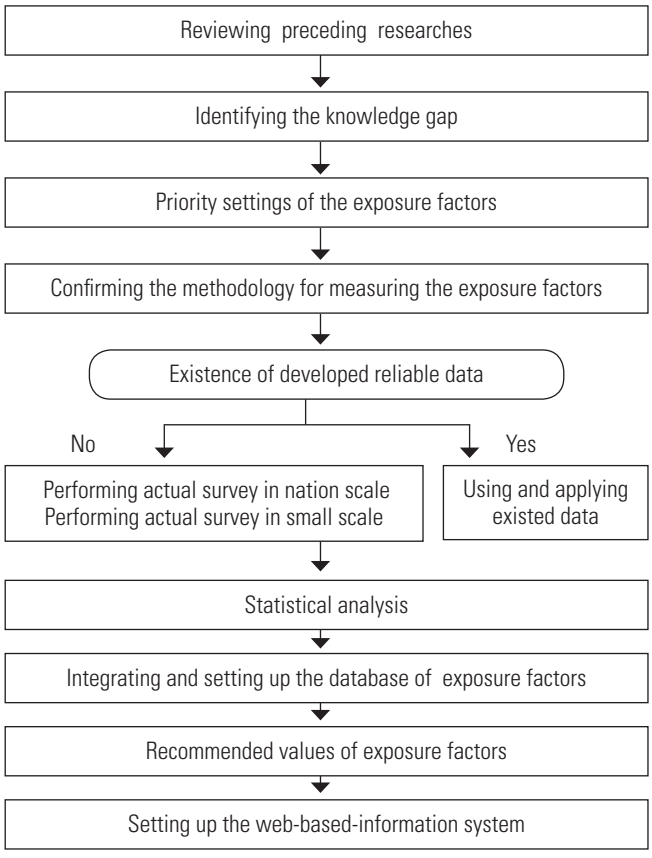

Figure 1. The practial research process in detail.

The next stage involved the review of the extent of domestic data accumulated on each of the 24 exposure factors and the categorization of development methods needed to calculate recommended values based on the results. Type 1 (direct use type) exposure factors, such as life expectancy, are backed up by highly reliable national-level domestic data and can be used as exposure factors right away. Type 2 (reanalysis type) exposure factors, including body weight and population and occupational mobility, are backed up by highly reliable national-level domestic data but needed statistical re-analysis before being used as exposure factors. Type 3 (conversion type) exposure factors, including body surface area, food ingestion exposure factors, and time spent in activities, are backed up by highly reliable national-level domestic data but require full-scale reorganization, recategorization, and reanalysis of raw data before being used as exposure factors. Finally, Type 4 (actual survey type) exposure factors had no pre-existing domestic data that were highly reliable for the development of exposure factors, and new investigations were needed. These factors included inhalation rate, intake of drinking water and soil, time spent in various places, and time spent on transportation, washing hands, washing the face, showering, bathing, and swimming. Table 1 presents the types of development methods and examples of exposure factors using each method according to the type of exposure factor.

In the US, where many previous studies have been conducted on each exposure factor, the core task in the development of the US EPA Exposure Factors Handbook was a process of obtaining recommended values such as selecting studies of high representativeness and reliability. In Korea, on the other hand, where very few studies on exposure factors have been published and in some cases, none, it was impossible to use the same development approach as the US. When there were

Table 1. Types of research

Type	Available national data	Action required	Exposure factors
Direct use type	Yes	Direct use	Life expectancy
Reanalysis type	Yes	Statistical reanalysis	Body weight
			Population mobility
			Occupational mobility
Conversion type	Yes	Data conversion	Body surface area
		Creating a new variable	Food ingestion factors
			Time spent on routine activities
Actual survey type	No	Actual survey	Inhalation rate
			Drinking water intake
			Soil ingestion
			Time spent in certain locations
			Time spent in vehicles
			Washing, showering, bathing and swimming

previous studies available containing data useful for calculating recommended values by examining, analyzing, and evaluating the findings according to the exposure factors, the researchers were able to take advantage of them. When there were no such previous studies, however, they had to design and conduct first-hand investigations and use the results for setting exposure factor levels. When designing an investigation into exposure factors, they considered the selection criteria for the studies that were used to calculate recommended values with the highest representativeness and reliability in the development process of the US EPA Exposure Factors Handbook and tried to meet selection criteria at least as rigorous. The rigor of criteria was determined based on that of the number of subjects, subjects' representativeness of the population, and methodologies.

Table 2 presents a sequential roadmap devised and implemented for the research tasks needed to develop the Korean Exposure Factors Handbook. In the first phase, the researchers calculated recommended values for which research data was available or could be calculated through relatively simple statistical reanalysis. These factors included life expectancy, body weight, population and occupational mobility, and body surface area. They also carried out a preliminary study for inhalation rate and intake of drinking water planned for the second phase, in which they investigated these two factors according

Table 2. Phase of the study

Phase	Development	Pilot study
1st	Body weight	Inhalation rate
	Life expectancy	Drinking water intake
	Body surface area	
	Occupational mobility	
	Population mobility	
2nd	Food ingestion factors	Human activity pattern
	Inhalation rate	
	Drinking water intake	
3rd	Activity factors	
	Soil ingestion	
	Exposure factors handbook	
	Web-based information system	

to the methodologies developed and confirmed in the first phase preliminary study and developed a set of food ingestion exposure factors. They also conducted a preliminary study for time activity exposure factors to be developed in the third phase. In addition, they compiled the exposure factors developed in the first, second, and third phase, produced the Korean Exposure Factors Handbook, and built a web-based information system.

Publication of the Korean Exposure Factors Handbook and Establishment of a Web-based Information System

After developing all the recommended values of each exposure factor, the researchers published the Korean Exposure Factors Handbook containing major information about the evaluation techniques related to the calculation of recommended values, principal statistical results, and available data. The handbook was comprised of an introduction and general, food ingestion, and activity exposure factors. The introduction addressed the need for an exposure factors handbook, plans for its utilization, and an overview of the research. The handbook presented statistical distribution values including means along with statistics by gender, age, and residential area according to the exposure factor. The body of the book consisted of an overview, calculation of recommended values, comparisons with cases from other countries, reliability, and limitations for each category of exposure factors. The overview covered the importance and significance of the subject exposure factors, overall content about the methodologies for the subject variables, and equations considering the usability of the exposure factors. The calculation of recommended values in-

cluded explanations about the data used, methodologies, and principal statistics as well as the recommended values themselves. More detailed information on recommended values was provided through comparison with the values developed by other countries.

Finally, a web-based information system was established to increase public accessibility and utilization. The web-based information system consisted of a research introduction, user's manual, general, food ingestion, and activity factors, and exposure assessment. It also had a download menu to help users easily download parts of or the entire content of the handbook [19].

CONCLUSION

Since the handbook is a national index for demonstrating the physiological, food ingestion, and behavioral characteristics of the Korean people, it can serve various purposes in addition to the environment including risk assessment. Other Asian countries have to borrow exposure factors from other countries for risk assessment until they can develop their own. It will benefit them more to consider the exposure factors of the Korean Exposure Factors Handbook and adjust them according to their situations rather than using the American counterparts as they are in spite of the huge differences in physiology, dietary habits, and life. The significance of exposure factors is multiplied when it comes to children since they react very sensitively to environmental contamination and chemicals due to incomplete development of nervous, respiratory and reproductive organs and have different food and water intakes, and breathing and metabolic rates per unit of body weight than adults. In 2002, the US EPA published its findings on an exposure factors handbook for children. In 2005, the European Union announced some recommended values for children's exposure factors [20].

The present study calculated children's intakes for all of the 12 exposure factors in the food ingestion category and children's recommended values for life expectancy, body weight, and intake of soil in the general exposure category. This study, however, failed to obtain first-hand data on body surface area, inhalation rate, intake of drinking water, and all the exposure factors of activity for children category due to limitations of data and other circumstances. Research should be conducted on the exposure factors left out of the study to develop an exposure factors handbook for children like that of the US.

This study used the body measurements of Korean people by the Korean Agency for Technology and Standards under the Ministry of Commerce, Industry, and Energy, the census, the data of the National Statistical Office, the basic statistical survey on the wage structure of workers, the National Health and Nutrition Examination Survey and other. Those national data are investigated and published annually or periodically. The present study used the latest data at the time of completion, but one can also consider a need for revision reflecting the updates to the data. However, frequent updates are not necessarily recommended since exposure factors have a different utility and nature from common statistics in that the standard values should be used to reduce the uncertainty of risk assessment. The US has revised the data only twice at intervals of over ten years [1]. Korea, however, has the potential for rapid economic and social changes and thus rapid changes to the exposure factors, which means that changes in the statistical values based on national data should be reviewed to judge whether a revision is needed or not. Performing additional investigations is necessary to compensate for the exposure factors that have been omitted, such as the characteristics of the residential environment, due to various limitations including restricted research time and budget and to evaluate the exposure factors that have characteristics unique to Korea.

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CONFLICT OF INTEREST

The authors have no conflicts of interest with the material presented in this paper.

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