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Development of Human Indices to Determine Both Returning Point of Residents and Damage Restoration for Response Protocol After the Chemical Accident

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Abstract: There were about 600 cases of large and small chemical accidents from 2014 to 2020 throughout Korea. The number of chemical accident cases after enforcement of AREEC and CSCA was declined sharply to 113, 79, and 57 in 2015, 2017, and 2019 respectively, which was reduced almost half of the number from 2015. Even if, the number of chemical accident cases was dramatically decreased, a response protocol for returning point of chemical accidental area residents and damage restoration is urgently required. Therefore, human indices were developed to determine returning point of residents and damage restoration after the chemical accident. To determine the returning point of residents after the chemical accident, a new concept, the standard man model was introduced as a human index, in which both H-code and its acute effects were main idea. To evaluate the applicability, a hydrogen fluoride leakage accident in Gumi was applied. The returning point were suggested as the conservative remission period of acute effects among relevant hazard effects and compared with actual returning point. The coverage of each age group were considered with reflecting average daily dose expected for actual residents. In addition, a relief-index as a social-scientific approach was reflected as well to apply the damage restoration. Actual returning point of residents in Gumi was 88 days; and that of standard man model suggested was 84 days. The expected amount of exposure at aged 12 or under was at least 2.35 times greater than that of this model, 40s, theoretically. However, their population ratio was less than 1%, so 99% of residents could be applied when the standard man model was applied. The relief-index was as an objective and quantitative methodology to apply the qualitative aspect. Although evaluated as a relatively positive result, there was a limitation such as the number of accident applied to the verification of standard man model. The relief index was also considered, but further research should be carried out to find threshold level for the relief.

Keywords: Chemical Accident, Returning Point of Residents, Standard Man Model, Remission Period, Acute Effect

1. Introduction

About 43,000 types of phase-in substances are being distributed in Korea, and every year, new chemicals are being registered and managed through AREEC and CSCA. Toxic Substances Control Act was revised to Act on Registration, Evaluation, Etc. of Chemicals (hereafter "AREEC") and Chemical Substances Control Act (hereafter "CSCA") in 2015 after death cases due to humidifier disinfectants in 2011 and hydrogen fluoride leakage accident in Gumi, 2012.

The number of chemical accident cases after enforcement of AREEC and CSCA was 113, 79, and 57 in 2015, 2017, and 2019 respectively. The number has reduced to almost half of the number from 2015, which is immediately after the enforcement. Before the enforcement of the acts, the government could not even properly figure out the chemical accident status, and a post management system in response to chemical accidents was not prepared. However, with establishment of National Institute of Chemical Safety and enforcement of the acts in 2015, systematic safety management of chemicals and chemical accidents was enabled, and enhancement of safety standards for facilities handling chemicals allowed predicting and responding to risk factors [1].

As a result of analyzing the types of accidents that occurred from 2014 to September 2020 in Korea, among total 559 cases of accidents were 431 cases of leakage, 33 cases of fire, 46 cases of explosion, and 49 other cases, and the majority of causes for such accidents was carelessness of the operators and insufficient management of the facilities. As for accident status by region, 201 cases occurred in Seoul·Gyeonggi (including Incheon), 75 cases occurred in Jeollanamdo·Jeollabukdo (including Gwangju), 174 cases occurred in Gyeongsangnamdo·Gyeongsangbukdo (including Daegu, Ulsan, and Busan), 95 cases occurred in Chungcheongnamdo·Chungcheongbukdo (including Daejeon), 10 cases occurred in Gangwondo, and 1 case occurred in Jejudo [2].

Such chemical accidents are causing damage to residents of the region including the workers. Due to the hydrogen fluoride leakage accident that occurred in Gumi, September 2012, at a chemical product import·manufacturing company, 5 workers died, and a number of residents received treatment [3]. At the time, due to lack of procedures for determining return and restoration point, problems were identified in the accident response system including reevacuation after the first return. While the number of chemical accident cases is decreasing, there is still a dire need for guidelines and response protocol for discussion of returning point of chemical accidental area residents and damage restoration. As the determining factor of residents return protocol after chemical accidents, medical scientific approach generally plays a key role, yet there are limitations. We have confirmed that even after removal of risk factors and threats of a certain danger, PTSD such as anxiety lasts. In other words, we have acknowledged that the definition of safety and relief differs. In such a reality, research for development of response protocol is insufficient. In this research, human indices were developed considering both medical scientific and social scientific approaches in predicting returning point of residents and damage restoration point after chemical accidents.

2. Method

Research was performed for development of human indices to determine returning point of residents and damage restoration point after chemical accidents that could occur during the manufacture or transfer process of phase-in substances and new chemicals being distributed in Korea.

2.1. Returning Point of Residents After Chemical Accidents

Standard Man Model Development

To determine returning point of chemical accidental area residents, the concept of standard man was introduced. The basic concept of standard man was defined by International Commission on Radiological Protection (ICRP) as a standard human adult body model used in radiation dose evaluation. Standard man introduced in this research was designed for determination of returning point of residents after chemical accidents based on the remission period of acute symptoms and diseases among hazard effects that could occur from chemical accidents. Reflecting consultations with occupational and environmental medicine (OEM) specialist, age group of 41 to 50, which is the median of life expectancy, was established as the criteria of standard man. The applicability of standard man model was verified by applying the weighted value 2 to the remission period of the standard age group for application to all the age groups including vulnerable groups on return of residents after chemical accidents.

To build basic database for establishment of remission period, 97 types of accident preparedness substances were used as the representative substances. As "chemicals designated·announced by the Minister of Environment according to Clause 39, as it is recognized that preparation for chemical accident is required according to Chemical Substances Control Act Clause 2 due to high possibility of chemical accident or concerns about large scale of damage in case of chemical accident arising from acute toxicity or explosiveness", they were decided to be effective in evaluating health effect of chemicals in a conservative approach. Major exposure routes reported in case of chemical accidents (oral, transdermal, eyes, respiratory system) and exposure routes of 97 types of accident preparedness substances were compared with each other and examined. To identify major exposure routes, the number of classified hazard risk cases of accident preparedness substances by relevant exposure route was checked and applied on a scale of 1 to 5. As a result of identifying exposure routes of accident preparedness substances and examining cases relevant to health hazard among hazard·risk classifications, 385 cases were confirmed. Such health hazards were classified into 5 categories: oral, dermal, eye, respiratory system, and CMR (carcinogen, mutagen, and reprotoxic). Health hazards were classified into 52 oral cases, 96 dermal cases, 71 cases of eyes, 104 cases of respiratory system, 35 CMR cases, and 27 other cases. Excluding other cases, the cases were applied on a scale of 1 to 5. To analyze and classify such health hazards into acute·chronic effects and sequelae, hazard code (H-code) was utilized.[4)] H-code were classified into 16 types by relevant route and described in the table below (Table 1). Four (4) major exposure routes in case of chemical accidents combined then classified into 11 groups, possible signs, symptoms, and diseases of each group were entered into database as acute effects, chronic effects, sequelae, and targeted organ-specific symptoms.

H-code and GHS (Global Harmonized System of Classification category and Labelling of Chemicals) classification category were classified referring to regulations on Classification, Labelling, Etc. of Chemicals and opinions of specialists (Table 2). H-code items of respiratory system, dermal, and eyes, which are exposure routes that could primarily cause acute effects to the human body in case of an actual chemical leakage accident, were reflected in the classification according to GHS classification category. The most conservative value among them mentioned in medical publications was applied as the remission period of acute symptoms and diseases relevant to each H-code.

Signs, symptoms, and diseases mixed among health hazards for each H-code were classified to the possible extent according to Korean Standard Classification of Diseases (KCD-code). KCD-code was established with International Classification of Diseases system of WHO as the frame to suit the situations of Korea, and the code classifies disease and other health problems listed in all forms of health and population movement records. The classification system consists of 6 levels: Chapter, Article, Section, Subsection, Subsubsection, and Subsubsubsection (excluding details of some classification items), and symptoms and diseases of each exposure route drawn in this research were classified by matching with KCD-code.

Table 1. *Definition and meaning of H-codes.*

Exposure routes	H-code	Definition	Meaning
Oral	H300	Acute toxicity cat. 1&2	Fatal if swallowed
	H301	Acute toxicity cat. 3	Toxic if swallowed
	H302	Acute toxicity cat. 4	Harmful if swallowed
Dermal	H310	Acute toxicity cat. 1&2	Fatal in contact with skin
	H311	Acute toxicity cat. 3	Toxic in contact with skin
	H312	Acute toxicity cat. 4	Harmful in contact with skin
	H314	Dermal corrosion/irritation cat. 1	Causes severe skin burns and eye damage
	H315	Dermal corrosion/irritation cat. 2	Causes skin irritation
	H317	Skin sensitization cat. 1	May cause an allergic skin reaction
Eyes	H318	Serious eye damage/irritation cat. 1	Causes serious eye damage
	H319	Serious eye damage/irritation cat. 2	Causes serious eye irritation
Respiratory system	H304	Aspiration hazard cat. 1	May be fatal if swallowed and enters airways
	H330	Acute toxicity cat. 1&2	Fatal if inhaled
	H331	Acute toxicity cat. 3	Toxic if inhaled
	H332	Acute toxicity cat. 4	Harmful if inhaled
	H334	Respiratory sensitization cat. 1	May cause allergy or asthma symptoms or breathing difficulties if inhaled

Table 2. *Matching between H-code and GHS classification.*

Health hazard	Cat. 1	Cat. 2	Cat. 3	Cat. 4
Acute toxicity (Inhalation)	H330 Fatal if inhaled		H331 Toxic if inhaled	H332 Harmful if inhaled
Aspiration hazard	H304 May be fatal if swallowed and enters airways			
Respiratory sensitization	H334 May cause allergy or asthma symptoms or breathing difficulties if inhaled			
Acute toxicity (dermal)	H310 Fatal in contact with skin		H311 Toxic in contact with skin	H312 Harmful in contact with skin
Dermal corrosion/irritation	H314 Causes severe skin burns and eye damage	H315 Causes skin irritation		
Skin sensitization	H317 May cause an allergic skin reaction			
Serious eye damage/irritation	H318 Causes serious eye damage	H319 Causes serious eye irritation		

The applicability of standard man model was evaluated as follows:

(1) Comparison between returning point of residents after hydrogen fluoride leakage accident in Gumi (CAS No. 7664-39-3) and returning point of residents suggested by standard man model.

(2) Comparison between average daily dose of each age group including standa.rd man and vulnerable groups.

(3) Applicability evaluation of standard man model by applying proportion and average daily dose of each age group of subjects of health impact assessment from the hydrogen fluoride accident area, Gumi.

Average daily dose (ADD) was estimated for each age group assuming the same exposure conditions (exposure frequency, exposure period, average time) and using the equation (1) [6].

Based on Korean Exposure Factors Handbook, the inhalation rate for age below 13 and age 65 or more, which are classified as vulnerable groups, was applied as described in the Table 3. As for infants and toddlers, as there are limitations in measuring inhalation rate, body weight and inhalation rate estimated for each level of activity using regression equation were reflected [6, 7]. While International Council on Harmonization defines vulnerable groups as age below 18 and age 65 or more, in this research, body weight and inhalation rate, which have huge influence on average daily dose, were considered, and conservative approach was taken. Variables such as environmental influence and underlying diseases of the subject population were not considered.

$$Average\ daily\ dose\ (ADD) = \frac{\text{Concentration of agent (mg/m}^3)\times\text{Inhalation rate (mg/m}^3)\times\text{Exposure frequency (day/year)}\times\text{Exposure duration (year)}}{\text{Body weight (kg)}\times\text{Averaging time (day)}} \quad (1)$$

Table 3. *Standard values of standard man and vulnerable group [6, 7].*

Type	Standard man (41-50 years)	Vulnerable group (<13 years & ≥65 years)
Inhalation rate (m^3/day)	15.5	11.1
Body weight (kg)	66.02	40.90

Table 4. *Differences between relief and safety.*

Relief	Safety
Public judgment	Expert judgment
A state of mind in which one feels joy or happiness without feeling worry or anxiety from the mind	Physical state protected from external physical and technical matters
Peace of mind and well-being without risk of incidents or incidents	Safe condition from incident or accident
No worries or anxieties about unforeseen dangers	No worries or anxieties regarding unforeseen danger

Lastly, age groups of actual subjects of health impact assessment from the hydrogen fluoride accident area, Gumi, were examined, and the applicability of standard man model was verified excluding populations influenced by expected exposure dose.

2.2. Damage Restoration

Damage restoration refers to recovering from the damage caused by disasters, accidents, etc. to the previous state. After return of residents, establishment of damage restoration point is required for conclusion of the chemical accident.

Relief Index

For return of residents after chemical accident, consideration of social scientific aspect is needed besides medical scientific approach.

As there is a gap between safety measured by experts and relief felt by the public, relief index was introduced as a way of closing such a gap.

Relief index survey developed by “Sungkyunkwan University SSK Risk Communication Research Center” was quoted and used as the indicator of conclusion of damage restoration. However, as the criteria of threshold were not established for relief index, the results should be evaluated relatively by setting a reference group. The difference between the concept of safety and relief is described in Table 4. Relief index survey consists of total 21 questions based on “summated Likert scale” among multi-item scales, and the index is estimated by evaluating the respondents' attitude or values, and classification is as described in Table 5. Relief index was estimated for each item on a scale of 1 to 11 applying equation (2) (n_number of question X_i_relief index for each question) and was indexed on a scale of 1 to 100 [8].

Table 5. *Composition of the relief index survey.*

Classification		Contents
Dimensional relief index	General (5 questions)	Respondent gender, age, residential area
	Part 1_beforehand (5 questions)	Concern level over the occurrence of accident Expectation of safety measures Usual relief (anxiety) Communication level related to chemical accident risk Preliminary management of overall safety and relief
	Part 2_response (5 questions)	Expertise in rapid response from government departments Manual compliance level Provided information level Cooperation level of residents Responses regarding overall safety, relief
	Part 3_follow-up (5 questions)	Identification of responsibility Compensation after accident Measures to prevent recurrence National follow-up measure Post management of overall safety, relief
Overall relief index	Overall evaluation (1 question)	Overall relief index regarding chemical accident risk

$$\text{Relief index} = \frac{1}{10} \times \sum_{i=1}^{n}(x_i - 1) \div n \times 100 \quad (2)$$

However, x_i is an itemized relief index.

Relief indexes estimated by examining damaged residents from the chemical accident area and the reference group (accidental area residents and clean area residents) shall be compared, and the point where the gap is closed shall be the damage restoration point. To utilize relief index, data of a clean area (ex. Jeju island) shall be obtained as the reference group.

3. Results

3.1. Major Exposure Route

Major exposure routes in case of a chemical accident and relevant exposure routes of 97 types of accident preparedness substances were compared·analyzed and listed in the order of weighted value of exposure: respiratory system (3.9), transdermal (2.8), eyes (1.9), oral (1.7) (Figure 1).

3.2. Standard Man Model

Acute effects among hazard effects of groups combined by exposure route are arranged in Tables 6 and 7. The weighted value "2" applied to the standard age group of standard man was verified in applicability evaluation 1. However, for chronic effect group and residents diagnosed with post-traumatic stress disorder (PTSD), continuous treatment and monitoring are needed.

Based on such symptoms and diseases of each exposure route, the remission period stated in medical publications, etc. was checked and entered into the database as described in Table 8.

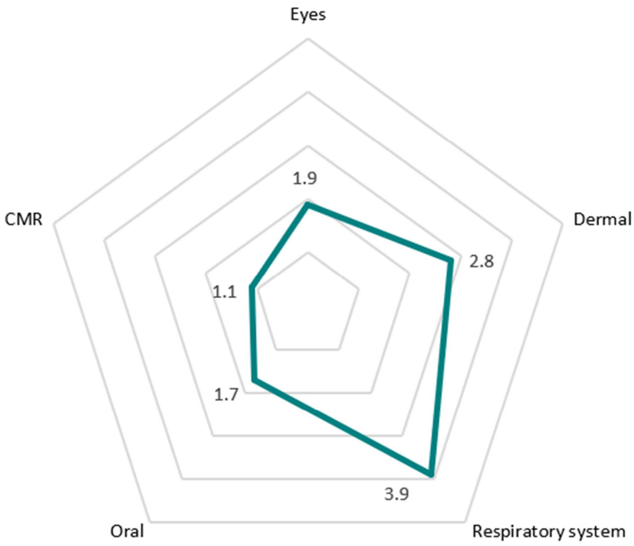

Figure 1. *The weighted values of major exposure routes for substances requiring preparation for accidents.*

Table 6. *Matrix of major exposure routes and their health hazard.*

Group	Exposure pathway matrix	Health hazard
1	Oral+dermal+eyes+respiratory system	Acute toxicity (oral, dermal, inhalation), skin sensitization, dermal corrosion/irritation, serious eye damage/irritation, aspiration hazard, respiratory sensitization
2	Dermal+eyes+respiratory system	Acute toxicity (dermal, inhalation), serious eye damage/irritation, aspiration hazard, respiratory sensitization
3	Oral+dermal+respiratory system	Acute toxicity (oral, dermal, inhalation), aspiration hazard, respiratory sensitization
4	Oral+dermal+eyes	Acute toxicity (oral, dermal), serious eye damage/irritation
5	Dermal+eyes	Acute toxicity (dermal), serious eye damage/irritation
6	Dermal+respiratory system	Acute toxicity (dermal, inhalation), aspiration hazard, respiratory sensitization
7	Oral+respiratory system	Acute toxicity (oral, inhalation), aspiration hazard, respiratory Sensitization
8	Eyes+respiratory system	Serious eye damage/irritation, aspiration hazard, respiratory sensitization
9	Oral	Acute toxicity (oral)
10	Eyes	Serious eye damage/irritation
11	Respiratory	Acute toxicity (inhalation), aspiration hazard, respiratory sensitization

Table 7. *Example of hazard effects for exposure routes (group 1_symptom, sign and disease).*

System	Acute effects	Chronic effects	Sequela
Respiratory system	Pneumonia, cough, dyspnoea, cyanosis, lung injury, bronchoconstriction, hectic, shallow and rapid respiration, sore throat, stridor, asthma, stuffiness, sputum, reactive airways dysfunction syndrome, thoracalgia, upper airway edema, respiratory failure, larynx and bronchial edema	Chronic respiratory disease, pneumonia, chronic asthma, lung inflammation, pulmonary angioneurotic edema, fibroid lung, bronchitis, chronic cough	Reactive airways dysfunction syndrome, lung injury, dyspnoea, respiratory stimulation, pulmonary tissue destruction, pulmonary function insufficiency, non-specific bronchial hypersensitivity, chronic obstructive pulmonary disease, chronic bronchitis, bronchoconstriction
Integumentary system	Skin burn, skin irritation, dermalgia, frostbite, erythema, blister, skirt ulcer, dermatitis, dermal necrosis, flare, rash, tumefaction, redness of skin, itchy	Dermatitis	Yellow skin coloration, skin scarring, skin burn
Eyes	Ocular pain, tear, eye irritation, corneal clouding, sensitive to the light, loss of sight, eye injury, blurred vision, eye inflammation, stain eyesight, corneal damage, ophthalmia, bloodshot eyes	Eye irritation	Loss of sight, visual defect, cataract, glaucoma

Table 8. *Example of KCD-code classification of symptoms and diseases for exposure routes.*

System	Symptoms or diseases	Remission period (D)	KCD-code
Respiratory system	Sputum		[R09.3] Abnormal sputum
	Bronchospasm	14 [9]	[J20] Acute bronchitis
	Upper airway stimulation	14 [10]	[J06] Acute upper respiratory infections of multiple and unspecified sites
	Bronchoconstriction	28 [11]	[J20] Acute bronchitis
	Cough	21 [12]	[R05] Cough
	Reactive airways dysfunction syndrome	15 [13]	[J39.3] Upper respiratory tract hypersensitivity reaction, site unspecified
	Pneumonia	14 [14]	[J68.0] Bronchitis and pneumonitis due to chemicals, gases, fumes and vapors
	Bronchitis	21 [15, 16]	[J68.0] Bronchitis and pneumonitis due to chemicals, gases, fumes and vapors
	Upper airway edema		[J39] Other diseases of upper respiratory tract
	Pharyngitis	14 [16]	[J02] Acute pharyngitis
	Nasal mucus	7 [16]	[J30] Vasomotor and allergic rhinitis

3.2.1. Applicability Evaluation_1

In the hydrogen fluoride leakage accident in Gumi, about 8 to 12 ton was leaked on September 27th, 2012, afternoon, and following the accident, residents within a radius of 1.3 km from the source of pollution evacuated. On September 28th, when hydrogen fluoride leakage was completely blocked, residents returned, but on October 6th, residents evacuated for the second time, the final point returning point of residents being December 24th, which was 88 days past the accident.[3)]

To verify the returning point of residents suggested by standard man model, the remission period of symptoms and diseases of group 2 (Table 6) that are matched with eyes, transdermal, and respiratory system, which are major exposure routes of hydrogen fluoride, was checked as described in Table 9.

Symptoms and diseases that can be caused by hydrogen fluoride leakage are cough, eye inflammation, diarrhea, headache, sore throat, dyspnoea, bloodshot eyes, erythema, etc., and the remission period checked is 21, 21, 21, 14, 10, 14, 21, and 42 days respectively. Accordingly, this research suggested 84 days (42 days*2) as the returning point by applying [standard man*weighted value (2)]. It can be confirmed that such a result does not differ much from the actual final returning point, which was 88 days.

Table 9. *Remission period of group 2_acute effects.*

Group 2 (H-code)			
Symptom	**Remission period (day)**	**Symptom**	**Remission period (day)**
Cough	21 [12]	Sore throat	10 [19]
Eye inflammation	21 [16]	Dyspnoea	14 [20]
Diarrhea	21 [16], [17])	Bloodshot eyes	21 [21]
Headache	14 [18]	Erythema	42 [22]

Table 10. *Comparison of ADD among age groups.*

Age	Exposure level by age group (mg/kg-day)	Exposure level of standard man (mg/kg-day)	Ratio
1≤ - <3 years	1.02E+00	2.35E-01	4.36
3≤ - <7 years	5.52E-01		2.35
7≤ - <13 years	3.21E-01		1.37
13≤ - <19 years	2.46E-01		1.05
19≤ - <25 years	2.05E-01		0.87
25≤ - <35 years	2.17E-01		0.92
35≤ - <45 years	2.38E-01		1.01
45≤ - <55 years	2.24E-01		0.95
55≤ - <65 years	2.34E-01		0.99
65≤ years	2.44E-01		1.04

3.2.2. Applicability Evaluation_2

Average daily dose was estimated for each age group (Table 10), and the ratio of 40's (2.35E-01 mg/kg-day), the standard age group of standard man, and the average of vulnerable groups, which are age 65 or more and age below 13 (2.72E-01 mg/kg-day), was 1.16, thus it was decided that the model could be applied to determine the returning point. However, as for children of age below 13, average body weight and inhalation differ much by age, and as a result of comparing exposure dose between subdivided groups, possibility of exposure 2.35 to 4.36 times higher compared to exposure dose of standard man was found among children of age below 7.

3.2.3. Applicability Evaluation_3

The number of subjects of health effect evaluation from the accident area was 1,364, and when the number by age group was checked as in Figure 2, age below 19 was found to be 301 [3]. As 288 middle school students were included in subjects of health effect evaluation from the accident area at the time, the number of residents of age below 13, for which high exposure is expected, is assumed to have been about 13. Based on this, it is judged that returning point suggested by standard man model could be applied to 99% of the residents of the area damaged by hydrogen fluoride accident in Gumi (Figure 3).

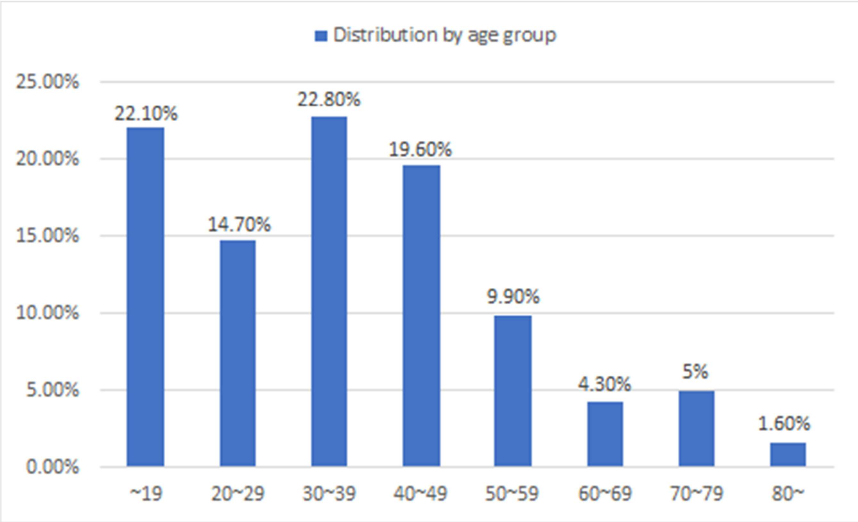

Figure 2. *Age groups of accidental area residents in Gumi.*

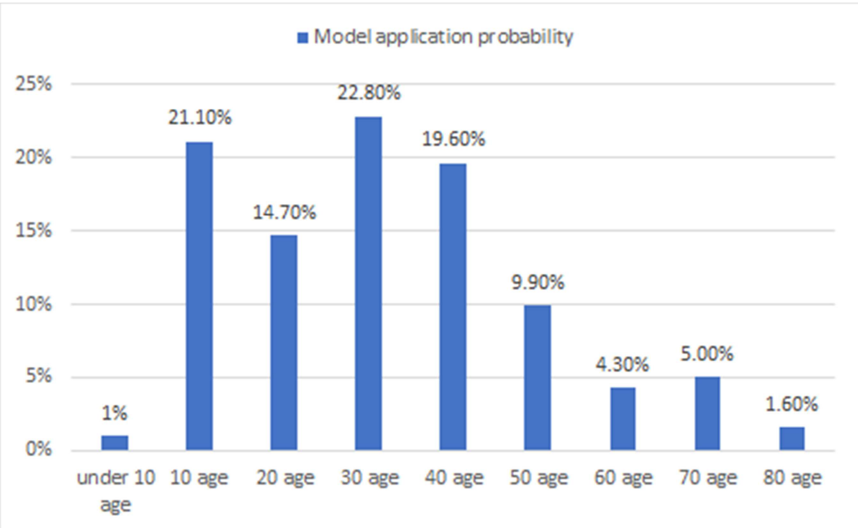

Figure 3. *Model application probability for accidental area residents in Gumi.*

3.3. Relief Index

Safety refers to evading acceptable or potential danger arising from physical·technical problems. Safety aside, there are limitations in deciding that residents damaged by chemical accident are feeling relieved. For example, in case of nuclear power plants, even if the government and experts emphasize that the risk is controllable and that the facility is safely managed, the public may not be relieved due to cases such as Fukushima.

For relief index of accidental area residents to reach the level of the reference group, medical service monitoring and continuous management shall be accompanied. According to studies by WHO, without communications with the accidental area residents, it may take not less than 18 months for damage restoration [23]. In order for these to be handled consistently, experts of relevant field and interested parties shall constitute deliberation committee and draw the damage restoration point. through agreement.

4. Discussion

As standard man model developed in this research is applicable to accidents of scale as big as or bigger than that of hydrogen fluoride accident that occurred in 2012, Gumi, rather than chemical accidents with limited effects on residents, so response protocol for each accident scale needs to be prepared. Also, besides protocol for each accident scale, vulnerability to possible symptoms and diseases by region shall be considered, and countermeasures shall be grafted accordingly. As a result of comparing the returning point of residents suggested by standard man model and the hydrogen fluoride accident in Gumi, the suggested returning point, 84 days, was similar to the actual case, 88 days, yet there are limitations in that the applicability was evaluated with a single case of accident, and it is thought that additional verification is required as the remission period for a part of symptoms and diseases among possible hazard effects has not been identified.

While the intent was to suggest a one-to-one matching as the standard disease code by matching symptoms and diseases caused by chemical accidents and KCD-code, there were limits in matching symptoms with KCD-code. Therefore, in determining returning point of residents with standard man model, the name of symptoms and diseases shall be presented, and KCD-code may be used as references [5]. To advance this model, additional research shall be conducted on remission period of relevant symptoms and diseases, classification of H-code, and KCD-code matching.

In utilizing standard man model, as for remission period, as all the possible acute effects were listed according to the health hazard of relevant H-code, symptoms and diseases reported by residents in the case of an actual accident may be included yet differ. As symptoms and diseases reported by residents when hydrogen fluoride accident occurred in Gumi are included in hazard effects of group 2, yet a part of symptoms did not occur, when standard man model is applied with symptoms that actually occurred, the suggested returning point may differ. However, as conservative approach was taken in application of the model, it is judge that it meets the purpose of the research.

Applicability evaluation in exposure dose approach may require verification of correlations between exposure dose, prevalence rate, and remission period. Especially considering vulnerable groups, as exposure dose for age below 7 or 13 has been confirmed to be at least 2.35 times higher, standard man model shall be applied with cautious considerations. However, as the weighted value (*2) was applied for return of residents including vulnerable groups, whether to apply the model shall be decided after additional research on sensitivity to diseases and prevalence rate, etc. especially for application to age below 13.

While the return rate estimated by applying standard man model according to the age distribution of residents of the hydrogen fluoride accidental area in Gumi was about 99%, the result may differ in other regions as proportions of age groups are different in each region. As a result of checking population and proportion of each age group in Gyeonggido and Gyeongsangbukdo (including Gumi) where chemical accidents occurred the most from 2014 to 2019, applying population census results, men and women below age of 14 were 1,798,661 and 301,028 respectively, which took up about 13% and 11%. Although, as population census results include male and female population parameters of age 13 to 14, the proportion of age below 13 cannot be estimated exactly, the proportion of age below 13 is assumed to be about 10% [24]. Considering this, it is simply judged that the model can be applied to 90% of residents.

Regarding certain risk factors such as chemical accidents, as there is a gap between risk level measured by experts and what is felt by the public, there are limitations in determining returning point of residents in medical scientific approach only. Currently, while there are tools for measurement of anxiety level related to risk, measurement tools for relief, in contrast with anxiety, are not prepared. Therefore, along with safety from dangers, evaluation of relief level in perspective of the public is required. Relief index is calculated using "summated Likert scale", which is evaluated to be highly practical and effective, and it is beneficial in that objective measurement is enabled as subjective intervention of the assessor is eliminated. Relief index, initially introduced in this research, is thought to be the starting point of research that can determine qualitative aspects in a quantitative manner.

The findings of this research, suggesting human indices practically useful to the evacuation of residents and obligation of business owners under the Risk Management Protocol stating action guides in the event of chemical accidents, are expected to be linked with governmental policies and utilized.

5. Conclusion

When status of response to chemical accidents is examined, research and development of response protocol regarding residents return and damage restoration are insufficient. This research developed human indices to predict returning point of residents and damage restoration point after chemical accident reflecting both medical scientific approach and social scientific approach.

As human indices, standard man model that predicts returning point of residents was developed based on the remission period of acute symptoms and diseases among hazard effects caused by chemical accidents, and the applicability evaluation was performed.

First, returning point of residents after hydrogen fluoride accident in Gumi and returning point of residents suggested by standard man model were compared, second, average daily dose of the standard age group of standard man and vulnerable groups were compared, third, population proportions of each age group of the hydrogen fluoride accident area in Gumi and proportion of residents whose return is enabled according to the exposure dose were estimated to evaluate standard man model. Along with the model, relief index was introduced to determine qualitative aspects in a quantitative manner and suggested as methodology of damage restoration point.

Although the applicability of standard man model was evaluated with returning point of residents of a single case of chemical accident, as available population parameters are limited, and the reference group was not selected intentionally, it is thought that the objectivity shall be admitted. It is also a positive result that the model is applicable to 99% of the accidental area residents due to population proportions of each age group of the relevant area. However, when exposure dose of each age group was examined, considering that the exposure dose for age below 13, especially below 7, is not less than 2.35 times higher, it was found that additional matters shall be considered for application to the relevant age group.

When simple comparison is made between population proportion of Gyeonggido where the most accidents occur within Korea and return probability according to exposure dose, it is thought that the model is applicable to about 90% of the population. In addition, the relief index was introduced in a social scientific approach, and the point where the gap between relief indexes of damaged residents from the chemical accidental area and the reference group is closed was established as the damage restoration point after chemical accident.

As a result of reviewing the applicability of standard man model, while there are limitations, it is thought that it shall be useful in judging the overall situation in early stages of accidents of a certain scale, in other words, accidents as large-scale as hydrogen fluoride accident in Gumi. In other words, in case of certain chemical accidents, responses such as proactively identifying probable symptoms and diseases and estimating returning point of residents shall be possible.

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References

[1] Energydaily [Internet]. c2020. Reduced chemical accidents after the implementation of the ‘ACT ON REGISTRATION, EVALUATION, ETC OF CHEMICALS’ and the ‘CHEMICAL SUBSTANCES CONTROL ACT; 2020 June 22 [cited 2020 October 19]. Available from: https://www.energydaily.co.kr/news/articleView.html?idxno=109297.

[2] National Institute of Chemical Safety [Internet]. c2020. Chemical accident status and cases; 2020 April 6 [cited 2020 October 5]. Available from: https://icis.me.go.kr/search/searchType2.do?menuNo=2020000&upperMenuNo=2000000&link=/search/searchType2.do&searchWord=#none

[3] Hube Global Co., Ltd. Hydrogen Fluoride Leakage Accident 3rd Stage Resident Health Impact Survey. National Institute of Environmental Research; 2014.

[4] National Law Information Center [Internet]. c2009. REGULATIONS ON CLASSIFICATION, LABEL LING, ETC. OF CHEMICALS (Article 11 (Hazard or Danger Statements)); 2009 January 5 [cited 2020 August 19]. Available from: http://www.law.go.kr/admRulLsInfoP.do?chrClsCd=&admRulSeq=2100000191770

[5] GOV.KR 24 [Internet]. c2017. The 8th Korean Standard Disease Classification (KCD-8) revision and announcement; 2017 July 26 [cited 2020 September 29]. Available from: https://www.gov.kr/portal/ntnadmNews/2198351

[6] Korean exposure factors handbook. National Institute of Environmental Research; 2019.

[7] Korean exposure factors handbook for children. National Institute of Environmental Research; 2019.

[8] Sungkyunkwan University SSK Risk Communication Research Center [Internet]. c2014. Relief Level Report on the Risk of New Infectious Diseases; 2014 October 14 [cited 2020 September 29]. Available from: https://shb.skku.edu/riskcomm/menu4/sub4_3.jsp?mode=view&article_no=101371&board_wrapper=%2Friskcomm%2Fmenu4%2Fsub4_3.jsp&pager.offset=0&board_no=1096

[9] FAIRVIEW [Internet]. c2000. Bronchospasm (Adult); 2000 [cited 2020 June 10] Available form: https://www.fairview.org/patient-education/115807EN

[10] Gozales R. CDC [Internet]. c2001. Nonspecific Upper Respiratory Tract Infection; 2001 [cited 2020 August 19] Available from: https://www.primarycare.tips/uploads/3/0/3/7/3037726/antibiotic20use20in20adults20respiratory20get20smart20cdc20academic20detail1.pdf

[11] Parsons JP, Hallstrand TS, Mastronarde JG, Kaminsky DA, Rundell KW, Hull JH, et al. An Official American Thoracic Society Clinical Practice Guideline: Exercise-induced Bronchoconstriction. American Journal of Respiratory and Critical CareMedicine. 2013; 187 (9): 1016-1027.

[12] Mcphee J, Papadakis A, Rabow W. CURRENT Medical Diagnosis and Treatment, 52th ed. New York: McGraw-Hill; 2013.

[13] Shah T, NMS Medicine Casebook. Baltimore, MD: Lippincott Williams & Wilkins; 2009.

[14] Andreoli TE, Benjamin IJ, Griggs RC, Wing EJ. Andreoli and Carpenter’s Cecil Essentials of Medicine, 8th ed. New York: Elsevier; 2010.

[15] AMERICAN FAMILY PHYSICIAN [Internet].c2000 Diagnosis and Treatment of Acute Bronchitis; 2000 December 1 [cited 2020 October 13]. Available from: https://www.aafp.org/afp/2010/1201/p1345.html.

[16] Tintinalli JE, et al. Tintinalli's Emergency Medicine: A Comprehensive Study Guide, 8th ed. New York: McGraw-Hill; 2015.

[17] Marx JA, Hockberger RS, Walls R. Rosen’s Emergency Medicine: concepts and clinicalpractice, 7thed. Philadelphia: Mosby; 2010.

[18] Ropper AH, Bron RH. Adams and Victor’s Principles of Neurology, 8th ed. New York: McGraw-Hill; 2005.

[19] Healthline [Internet]. c2005. How Many Days Does It Take to Recover from a Sore Throat?; 2018 October 23 [cited 2020 October 19]. Available from: https://www.healthline.com/health/how-long-does-asore-throat-last

[20] Family Practice Notebook [Internet]. c1995. Acute Respiratory Distress Syndrome; 2020 October 13 [cited 2020 October 19]. Available from: https://fpnotebook.com/Lung/Failure/ActRsprtryDstrsSyndrm.htm

[21] Seoul national university hospital [Internet]. c2010. Medical encyclopedia; 2010 [cited 2020 October 19]. Available from: http://www.snuh.org/health/encyclo/view/12/2/2.do

[22] Braunwald E, Isselbacher KJ, Petersdorf RG, et al. Harrison's Manual of Medicine, 17th ed. New York: McGraw-Hill; 2009.

[23] World Health Organization (WHO). Manual for the Public Health Management of Chemical Incidents. 2009.

[24] SGIS Statistical geographic information service [Internet]. c2015. 2020 Population and housing census; 2015 [cited 2020 September 5]. Available from: https://sgis.kostat.go.kr/jsp/pyramid/pyramid1.jsp