ACTUAL SITUATION OF ENVIRONMENTAL INJUSTICE BY COMPARATIVE ANALYSIS OF SOCIOECONOMIC CHARACTERISTICS AMONG LOCAL GOVERNMENTS BASED ON CHEMICAL SUBSTANCE EMISSION– A CASE IN KOREA

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Abstract - Studies on domestic environmental justice are mainly focused on the domestic application and legalization of environmental justice, and the nationwide analysis using practical indicators has hardly been carried out. On the other hand, foreign studies on environmental justice have been focused on specific indicators such as the distribution of air pollutants and the location of environmentally hateful facilities using national data. Therefore, this study compared the socioeconomic characteristics of the local governments' chemical substance emissions to understand the actual condition of domestic environmental injustice. To do so, the chemical substance emissions in each city, county and district nationwide were divided according to rank, and the socioeconomic characteristics of local governments, which were classified by rank, were compared. According to the analysis, 70% of total chemical substance emissions were found in 23 local governments, and 90% were observed in 49 local governments. In addition, there was a significant difference in the numbers of the socioeconomically disadvantaged exposed to chemical substances between 189 local governments (excluding groups involving 70%, 80% and 90% of accumulated chemical substance emissions, 229 local governments, and 49 local governments that emit 90% of chemical substances out of 229 local governments) and 60 local governments that do not emit chemical substances at all.

Keywords - Environmental justice, Environmental Injustice, Chemical substance emissions, Chemical facility, Socio-economic characteristics.

I. INTRODUCTION

Rapid industrialization and urbanization have caused serious environmental damage in local communities. In addition, the damage structure according to environmental pollution reflects the existing social structure. In other words, the environmental damage has been rapidly transferred to the socially disadvantaged through the existing unequal social structure, and this issue has been conceptualized as environmental injustice (Hae-soo Kwon. 2002).

However, discussions on environmental justice have not been specified, and indicators and analysis methods for environmental injustice investigation have not been presented in detail (Young-woonBahn, 2007). In Korea, there have been various studies on environmental justice, but they have been focused on the domestic application and legalization of environmental justice, such as possibility of institutionalization about environmental justice (Ram Ha 2013), recognition of environmental justice (Hyung Sun Park, Sang Jun Nam 2016, Young Bok Kang, Young Mi Song 2003), and redefinition of environmental justice (Jae Mok Park 2006). Thus, these studies have been only qualitative analysis, such as studies on damage cases (Sung Bae Kim 2013, Ye Yong Choi, HawJinRyu 2005). On the other hand, studies on environmental justice in other countries are mainly focused on analytical aspects using specific indicators and national data (H Huang 2017). For example, there was a case study of environmental inequality by comparing and analyzing socioeconomic indicators of chemical substances and metal substances (F Occelli, 2016). However, the above study used the exposure levels to chemical substances and racial/minority groups as indicators. Therefore, this study derived the following research questions to examine the status of environmental injustice. First, were the chemical substances emitted in Korea concentrated in specific local governments? Second, were there more children, elderly people, and recipients of national basic livelihood guarantees in the areas where the chemical substance emissions were concentrated? The first question is related to spatial condition injustice, and the second question is to confirm whether socially/biologically disadvantaged persons are unfairly exposed to environmental risks.

The purpose of this study is to investigate the spatial distribution characteristics of chemical substance emissions and analyze the actual status of the domestic environmental injustice by comparing and analyzing the socioeconomic characteristics between the local governments exposed to chemical substances and non-exposed local governments.

II. DETAILS EXPERIMENTAL

2.1.Research hypothesis establishment and analysis method

In terms of distributive justice among the three aspects of environmental justice, chemical substance emission, location of emission facilities, and socioeconomic characteristics were analyzed.

Overseas studies found that the level of exposure to chemical substances was high in areas where a minority group lived and poor areas, and that there was a significant difference in levels of exposure between those areas and the areas where the rich lived (Hongtai Huang, 2016). In addition, an analysis of metal pollution levels and socioeconomic indicators in specific areas revealed that there was environmental inequality (FlorentOccellia,d., Rachel Bavdekb,c., 2016). In this study, the following hypotheses were established based on the causal relationship between chemical substances and socioeconomic indicators that were verified in previous studies.

Hypothesis 1: Chemical substances emitted in Korea would be concentrated in specific local governments.

Hypothesis 2: Socioeconomically disadvantaged would reside discriminatorily in areas where chemical substance emissions are concentrated or non-concentrated areas.

Hypothesis 2-1: The proportion of children under the age of 14 would be higher in areas where chemical substance emissions are concentrated.

Hypothesis 2-2: The proportion of population over 65 years or older would be higher in areas where chemical substance emissions are concentrated.

Hypothesis 2-3: The proportion of population aged under 14 years old and over 65 years old would be higher in areas where chemical substance emissions are concentrated.

Hypothesis 2-4: The proportion of recipients of national basic livelihood guarantees would be higher in areas where chemical substance emissions are concentrated.

To verify Hypothesis 1, socioeconomic indicators were classified into biological indicators and economic indicators. Biological indicators included the percentage of people under 14 years old, the percentage of people over 65 years old, and the percentage of people under 14 years old and over 65 years old. The percentage of recipients of national basic livelihood guarantees was used as an economic indicator.

Using the indicators above, 229 local governments in Korea were analyzed, and the analysis procedure is as follows. First, the spatial distribution characteristics of chemical substance emissions were investigated through distribution analysis. The cumulative ratio was calculated based on the total amount of chemical substance emissions, and the corresponding cities, counties, and districts were identified. Lastly, the four socioeconomic indicators were used as dependent variables, and cumulative rates based on chemical substance emissions were set as factors. The statistical significance of regional differences was verified through one-way ANOVA. In addition, the difference between each comparison group was analyzed using the Scheffe test. The period of the study was 2015 based on the Population and Housing Census.

2.2.Data construction method

To diagnose the actual status of environmental injustice, relevant data were collected from government agencies such as Statistics Korea and Ministry of Environment, information disclosure requests, and public institution information systems. Since then, data have been transformed into a consistent format by checking missing or redundant data and refining addresses. Data were classified and indexed according to the characteristics. The data were then entered and stored using Arc GIS 10.1 program. Analysis and statistical significance verification were carried out using a SPSS statistical analysis program.

2015 chemical substance emissions data for each company in 2015, which were provided by National Institute of Chemical Safety, were used. Based on the address of the company, the address was refined and coded through the X-ray map provided by Biz GIS, and the address was applied to Arc GIS. Based on the refined data, the total amount of chemical substance emissions by region was added by calculating the total amount of environmental emissions. Socioeconomic indicators constituted the total population in each city, county, and district, the population under 14 years old, population over 65 years old, the population under 14 years old and over 65 years old, and the recipients of national basic livelihood guarantees.

III. RESULTS AND DISCUSSION

3.1. Spatial distribution characteristics

3.1.1.Distribution characteristics of chemical substance emission facility

In 2015, there were a total of 3,634(53,732,487kg/year) chemical substance emission facilities nationwide, and the number of emission facilities implemented by GIS was 3.594 (53,417,185kg/year). Based on the emission facilities data implemented by GIS, the largest portion (1,148 facilities, 31.94%) was found in the metropolitan areas (Seoul, Gyeonngi and Incheon), with facilities being the most concentrated in Ansan, Gyeonggido (284 facilities, 7.9%), followed by Cheongju, Chungbuk (123 facilities, 3.4%), and Changwon, Gyeongnam (121 facilities 3.4%) (Fig.1,2).

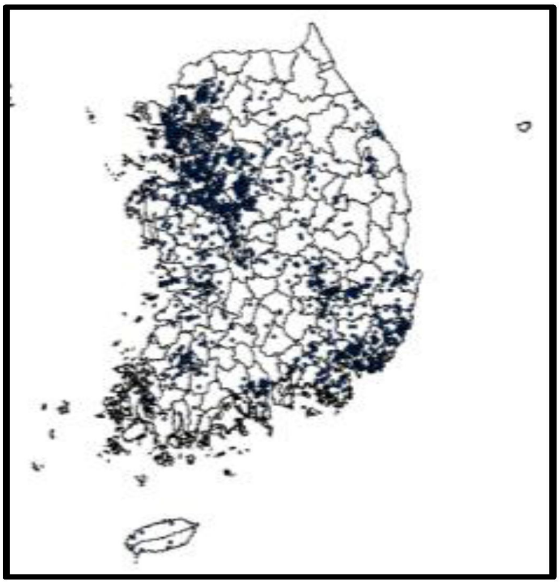

Fig.1. Location of chemical substance emission facilities

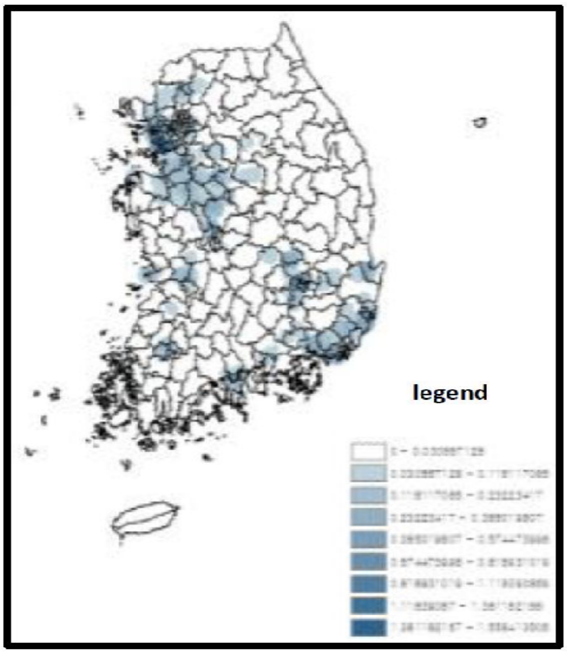

Fig.2. Density of chemical substance emission facilities

3.1.2.Distribution characteristics of chemical substance emission standard

The total amount of chemical substance emissions was greater in the following order: Gyeonggi-do (11,910,532.5kg/year), Gyeongnam (8,897,968.7 kg/year), and Ulsan (8,150,835.1 Kg/year), which accounted for 54% of the total emission amount in Korea (53,732,487kg/year). In addition, about 17% of total chemical emission was concentrated in Donggu, Ulsan (5,203,055 Kg/year) and Geoje, Gyeongnam (4158465 Kg/year) at the city, county and district unit. This means that the area where the chemical substance emission facilities are concentrated is not always the area with the most chemical substance emission. In other words, a large number of facilities does not always lead to high chemical substance emission. However, it is unusual for chemical substances to be emitted in a specific metropolitan city or a specific city, county, or district. This disproves that the certain areas where industrial complexes are concentrated are unfairly exposed to chemical substance emissions.

3.1.3. Distribution characteristics of carcinogenic substance emission facility and quantity standard

When the emitted substances were subdivided based on the International Agency for Research on Cancer (IARC) criteria for carcinogenicity, the highest emissions of Group 1 carcinogens (carcinogenic to humans) was Gwangju (335,738.8 Kg/year), followed by Gyeonggi-do (195,059.6 Kg/year) and Gyeongbuk (140,333.4 Kg/year). The highest emission was observed in Gwangsan-gu, Gwangju City (335,738 Kg/year) at the city, county and district unit. The highest emission of Group 2 carcinogens (estimated or possible carcinogens in human body) was Chungbuk (1,553,789.2 Kg/year), followed by Ulsan (1.454.704.4 Kg/year) and Gyeongnam (1,229,454.6 Kg/year). The highest emission was observed in Donggu, Ulsan (1,007,674 Kg/year) and Cheongju, Chungbuk (997,373 Kg/year) at the city, county and district unit (Figures 3,4).

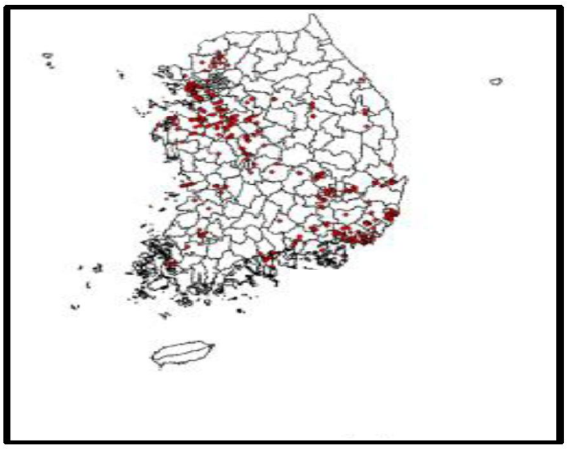

Fig.3. Location of Group 1 carcinogens facilities

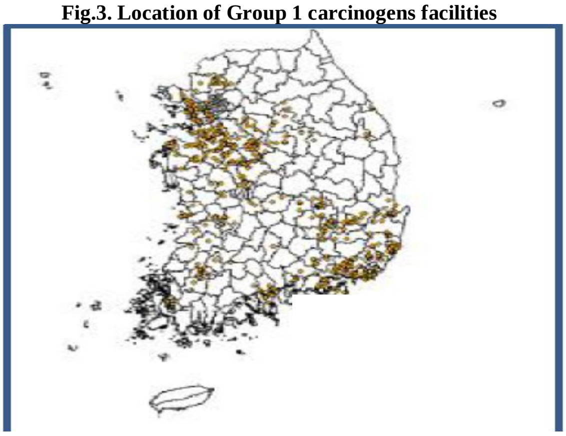

Fig.4. Location of Group 2 carcinogens facilities

3.1.4. Regional difference analysis

Based on the total amount of emissions, the emission amount of chemical substances was compared and analyzed with the population under 14 years old, the population over 65 years old, and the population under 14 years old and over 65 years old, and the recipient of national basic livelihood guarantees. Based on the total amount of emissions, 229 local governments nationwide were classified into 70% cumulative area, 80% area, and 90% area (Table 1). Analyzed groups consisted of six groups: 23 areas of 70%, 34 areas of 80%, 49 areas of 90%, 229 whole areas (group 1), 180 areas of lower 10% (group 2), and 61 areas where emitted substances were not detected (group 3). As a result, the average percentage of the population under 14 years old tended to be higher in the area where the emissions were concentrated. On the other hand, the average percentage of the recipients of national basic livelihood guarantees tended to be higher in the regions other than the cumulative areas. The percentage of population over 65 years old and the population under 14 years old and over 65 years old did not show a clear tendency of average values by cumulative ratio (Table 2).

Table1: City, county, and district by cumulative ratio

Cumulative ratio	City, county, and district
70% area	Donggu in Ulsan, Geoje in Gyeongnam, Youngam in Jeonnam, Hwasung in Gyeonggi, Ansan in Gyeonggi, Changwon in Gyeongnam, Pyungtaek in Gyeonggi, Chungju in Chungbuk, Cheonan in Chungnam, Namgu in Ulsan, Gwangsan in Gwangju, Iksan in Jeonbuk, Gumi in Gyeongbuk, Ulju in Ulsan, Yeosu in Jeonnam, Umsung in Chungbuk, Ansung in Gyeonggi, Gangseo in Busan, Gosung in Gyengnam, Gimpo in Gyeonggi, Jeungpyeong in Chungbuk, Asan in Chungnam, Seosan in Chungnam 3
80% area	Namdong in Incheon, Ohsan in Gyeonggi, Gwangmyung in Gyeonggi, Seogu in Gwangju, Yangsan in Gyeongnam, Tongyoung in Gyeongnam, Yongin in Gyeonggi, Gunsan in Jeonbuk, Wonju in Gangwon, Dalsung in Daegu, Siheung in Gyeonggi
90% area	Gyeongju in Gyeongbuk, Moonkyung in Gyeongbuk, Seogu in Daegu, Chilgok in Gyeongbuk, Pohang in Gyeongbuk, Bukgu in Ulsan, Wanjoo in Jeonbuk, Hongsung in Chungnam, Saha in Busan, Chungju in Chungbuk, Icheon in Gyeonggi, Jungeoup in Jeonbuk, Seogu in Incheon, Kimhae in Gyeongnam, Bukgu in Daegu

Table2: Statistical table by cumulative ratio of chemical substance emissions

		N	Mean	Standard deviation	Standard error	95% confidence interval about mean		Minimum	Maximum
						Lower limit	Upper limit		
Population under 14 years old	0.7	23	.14639636	.022010122	.004589428	.13687847	.15591425	.101188	.195443
	0.8	34	.14662983	.019570456	.003356306	.13980138	.15345829	.101188	.195443
	0.9	49	.14122493	.022614244	.003230606	.13472936	.14772050	.083867	.195443
	1	229	.11558609	.026954717	.001781218	.11207633	.11909584	.057574	.195443
	2	180	.10860662	.023651220	.001762858	.10512796	.11208528	.057574	.186803
	3	61	.10076919	.023091215	.002956527	.09485525	.10668312	.057574	.176459
	total	576	.11707965	.028077708	.001169904	.11478184	.11937746	.057574	.195443
Population over 65 years old	0.7	23	.12358833	.049865717	.010397721	.10202477	.14515188	.072534	.266578
	0.8	34	.11940201	.043199795	.007408704	.10432889	.13447513	.072534	.266578
	0.9	49	.12904465	.050025921	.007146560	.11467553	.14341377	.064346	.266578
	1	229	.18657171	.083334164	.005506877	.17572083	.19742259	.064346	.385112
	2	180	.20223185	.083797390	.006245889	.18990681	.21455690	.069387	.385112
	3	61	.22288248	.092728348	.011872648	.19913365	.24663131	.081023	.385112

	합계	576	.18393728	.084647619	.003526984	.17700994	.19086462	.064346	.385112
Population under 14 years old and over 65 years old	0.7	23	.26998468	.039751368	.008288733	.25279490	.28717446	.206723	.367766
	0.8	34	.26603184	.034780002	.005964721	.25389652	.27816715	.206723	.367766
	0.9	49	.27026958	.037972066	.005424581	.25936273	.28117643	.206723	.367766
	1	229	.30215779	.065149767	.004305218	.29367469	.31064090	.206723	.458189
	2	180	.31083848	.068305273	.005091174	.30079203	.32088492	.210278	.458189
	3	61	.32365166	.077925225	.009977303	.30369409	.34360924	.214465	.458189
	합계	576	.30101693	.065542855	.002730952	.29565307	.30638079	.206723	.458189
Recipients of national basic livelihood guarantees	0.7	23	.02938839	.012483586	.002603008	.02399008	.03478669	.012943	.058723
	0.8	34	.03029110	.012914000	.002214733	.02578519	.03479700	.007725	.058723
	0.9	49	.03350544	.014667033	.002095290	.02929258	.03771831	.007725	.081666
	1	229	.04256600	.017331097	.001145271	.04030933	.04482267	.007725	.098118
	2	180	.04503248	.017213770	.001283039	.04250065	.04756431	.011361	.098118
	3	61	.04848149	.018893410	.002419053	.04364266	.05332032	.011361	.089568
	Total	576	.04194171	.017611450	.000733810	.04050044	.04338299	.007725	.098118

3.2.Statistical significance of regional differences

3.2.1.Cumulative ratio and percentage of population under 14 years old

The one-way ANOVA was conducted to examine the statistical significance of regional differences in chemical substance emissions, percentage of population under 14 years old, percentage of population over 65 years old, percentage of population under 14 years old and over 65 years old, and percentage of recipients of national basic livelihood guarantees. As shown in Table 3, as a result of analysis of variance on the emission amount of chemical substances and population under 14 years old, there was a statistically significant regional difference between the cumulative ratio and percentage of population under 14 years old ($F=35.519$, $df=575$, $p< 0.05$). As a result of the post-hoc test on the differences in the percentage of population under 14 years old between each group, 70% area (0.14639636), 80% area (0.14662983), 90% are (0.14122493), group 1 (0.11558609), group 2 (0.10860662), and group 3 (0.10076919) showed differences.

Table3: Relationship between cumulative ratio and percentage of population under 14 years old

Group	N	Mean	Standard deviation
70%	23	0.14639636	0.022010122
80%	34	0.14662983	0.019570456
90%	49	0.14122493	0.022614244
1	229	0.11558609	0.026954717
2	180	0.10860662	0.023651220
3	61	0.10076919	0.023091215

F	df	P-value	Difference group
35.519	575	0.000	For each group

3.2.2. Cumulative ratio and percentage of population over 65 years old

As a result of analysis of variance on the relationship between chemical substance emissions and the percentage of population over 65 years old, as shown in Table 4, there was a statistically significant regional difference between the cumulative ratio and the percentage of the population over 65 years old (F=16.734, df=575, p< 0.05). As a result of the post-hoc test on the difference in the percentage of population over 65 years old, 70% area (0.12358833), 80% area (0.11940201), 90% area (0.12904465), group 1 (0.18657171), group 2 (0.20223185), and group 3 (0.22288248) showed differences.

Table4: Relationship between cumulative ratio and percentage of population over 65 years old

Group	N	Mean	Standard deviation
70%	23	.12358833	.049865717
80%	34	.11940201	.043199795
90%	49	.12904465	.050025921
1	229	.18657171	.083334164
2	180	.20223185	.083797390
3	61	.22288248	.092728348
F	df	p-value	Different group
16.734	575	0.000	For each group

3.2.3. Cumulative ratio and percentage of population under 14 years old and over 65 years old

As a result of analysis of variance on the relationship between chemical substance emissions and the percentage of population under 14 years old and over 65 years old, as shown in Table 5, there was a statistically significant regional difference between the cumulative ratio and the percentage of the population under 14 years old and over 65 years old (F=7.843, df=575, p< 0.05). As a result of the post-hoc test on the difference in the percentage of population under 14 years old and over 65 years old, 70% area (0.26998468), 80% area (0.26603184), 90% area (0.27026958), group 1 (0.30215779), group 2 (0.31083848), and group 3 (0.32365166)showed differences.

Table5: Relationship between cumulative ratio and percentage of population under 14 years old and over 65 years old

Group	N	Mean	Standard deviation
70%	23	.26998468	.039751368
80%	34	.26603184	.034780002
90%	49	.27026958	.037972066
1	229	.30215779	.065149767
2	180	.31083848	.068305273
3	61	.32365166	.077925225
F	df	p-value	Difference group
7.843	575	0.000	For each group

3.2.4. Cumulative ratio and percentage of recipients of national basic livelihood guarantees

As a result of analysis of variance on the relationship between chemical substance emissions and the percentage of recipients of national basic livelihood guarantees, as shown in Table 6, there was a statistically significant regional difference between the cumulative ratio and the percentage of recipients of national basic livelihood guarantees (F=11.347, df=575, p< 0.05). As a result of the post-hoc test on the difference in the percentage of recipients of national basic livelihood guarantees, 70% area (0.02938839), 80% area (0.03029110), 90% area (0. 03350544), group 1 (0. 04256600), group 2 (0. 04503248), and group 3 (0. 04848149)showed differences.

Table6:Relationship between cumulative ratio and percentage of recipients of national basic livelihood guarantees

Group	N	Mean	Standard deviation
70%	23	.02938839	.012483586
80%	34	.03029110	.012914000
90%	49	.03350544	.014667033
1	229	.04256600	.017331097
2	180	.04503248	.017213770
3	61	.04848149	.018893410

F	df	p-value	Difference group
11.347	575	0.000	For each group

3.3. Post-hock test

Post-hoc test was conducted to determine the specific mean difference between the significant indicators and groups at the significance level of 0.05. To do so, Scheffe's method was used to present more accurate results because six groups and four indicators had to be compared. Group 1, 2, and 3 showed statistically significant results with 70% group as a result of comparing 70% group with 90% group, group 1, group 2, and group 3 and testing the proportion of population under 14 years old. 80% group showed significant results with group 1, 2, and 3, and 90% group showed significant results with group 1, 2, and 3. This means that there were statistically significant differences among the areas where a large amount of emitted substances existed, entire nation (group 1), the lower 10% in cumulative ratio areas (group 2), and areas that did not have emitted substances (group 3). As a result of setting the subjects as the same group and comparing the size of the groups, the result was a, b, c>d, e, f (a= 70% group, b= 80% group, c= 90% group, d=group 1, e=group2, f=group 3).

In terms of the percentage of population over 65 years old, group 1, 2, and 3 showed statistically significant results with 70% group. 80% group showed significant results with group 1, 2, and 3, and group 90% showed significant results with group 1, 2, and 3. This means that there were statistically significant differences among the areas where a large amount of emitted substances existed, entire nation (group 1), the lower 10% in cumulative ratio areas (group 2), and areas that did not have emitted substances (group 3). However, as opposed to the percentage of the population under 14 years old, as a result of setting the subjects as the same group and comparing the size of the groups, the result was a, b, c<d, e, f (a= 70% group, b= 80% group, c= 90% group, d=group 1, e=group2, f=group 3).

In terms of the population under 14 years old and over 65 years old, group 3 showed significant results with 70% group. 80% group showed significant results with group 2 and 3, and 90% group showed significant results with group 2 and 3. In other words, 70% group, 90% group, group 1 and group 2 cannot be compared with other groups. The size of the group was b<a, c, d, e<f (a= 70% group, b= 80% group, c= 90% group, d=group 1, e=group 2, f=group 3).

In terms of the percentage of recipients of national basic livelihood guarantees, 70% group showed significant results with group 1, 2, and 3. 80% group showed significant results with group 1, 2, and 3. 90% group showed significant results with group 1, 2, and 3. Group 1 did not show significant results with group 2 and 3. Group 2 and 3 did not show significant results with each other. The size of the group was a, b<c, d<e, f (a= 70% group, b= 80% group, c= 90% group, d=group 1, e=group2, f=group 3).

3.4. Discussion on the hypothesis

As a result of investigating the concentration of chemical substances in certain local governments (Hypothesis 1), we confirmed that emissions of chemical substances were concentrated in specific local governments when determining the spatial distribution characteristics. About 54% of total emissions were concentrated in Gyeonggido, Gyeongnam, and Ulsan in terms of metropolitan city and province, and about 17% of total emissions were concentrated in Donggu, Ulsan, and Geoje, Gyengnam. Thus, we demonstrated the hypothesis that chemical substance emissions were concentrated in specific local governments.

To identify the ratio of the socioeconomically disadvantaged in areas where chemical substance emissions were concentrated and non-concentrated areas (Hypothesis 2), we subdivided the socioeconomically disadvantaged indicators into the percentage of population under 14 years old, the percentage of population over 65 years old, percentage of population under 14 years old and over 65 years old, and percentage of recipients of national basic livelihood guarantees. Hypothesis 2-1 predicted that the percentage of population under 14 years would be higher in areas where chemical substance emissions were concentrated. As a result of examining the relationship between the area where chemical substance emissions were concentrated and the percentage of population under 14 years old, there were statistically significant differences between chemical substance emission groups. Thus, the hypothesis that the percentage of population under 14 years old would be higher in areas where chemical substance emissions were concentrated was demonstrated. However, hypotheses 2-2, 2-3, and 2-4 showed different aspects. The percentage of population over 65 years old, percentage of population under 14 years old and over 65 years old, and percentage of recipients of national basic livelihood guarantees showed statistically significant differences. However, the percentage of population was higher in regions with less emissions. This result indicates regional gap resulting from chemical substance emissions and environmental injustice. However, unlike existing overseas studies that socioeconomic indicators were low in areas where chemical and metal substances were concentrated, this study showed Korea's unique characteristics.

CONCLUSIONS

The environmentally hazardous facilities emit 70% of total chemical substances in 23 out of 229 areas. This indicates that chemical substance emissions are very seriously concentrated in certain regions. In addition, the percentage of population under 14 years old was higher in areas with a high amount of chemical substance emissions than that in those with low emissions, while the percentage of recipients of national basic livelihood guarantees was lower. This may have been the result of Korea's industrial location policy. In the areas where industrial complexes and individual factories could be constructed, chemical substance emission facilities as well as general factories were concentrated. After that, producible population and children started to live in the neighboring areas because of economic reasons. In addition, chemical emission facilities may have invaded into the existing residential areas or the urban expansion may have been the cause. Chemical substances are an example showing the local characteristics according to the domestic industrial development structure. Industrial complexes that have been developed due to national industrial complex development projects and geographical characteristics greatly impact the social, economic and demographic structure of the area.

As this study is macroscopic study that sets up and analyzes the whole country at the city, county and district unit, so it has a limitation of not being able to closely examine the characteristics of an area. To analyze the difference within areas or between specific areas in more detail and derive meaningful values, it is necessary to construct a solid study design through microscopic analysis and techniques of subdivided spatial units. In this regard, future studies should empirically analyze regional differences through more detailed data construction and bottom-up approach.

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