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A Quantitative Environmental Justice Analysis in Yokohama, Japan: Relationship between Social Indicators and Environmental Quality

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Abstract

In comparison with the US and other countries, there is inadequate literature of quantitative analysis on matters of environmental justice in Japan. By conducting a case study on Yokohama, this research statistically investigated the spatial relationship between the socio-demographic characteristics of population and three environmental qualities: proximity to hazardous industrial waste management facilities (i.e. special control industrial waste management facilities), air pollution exposure, and accessibility to public elementary schools. The results show that higher percentages of blue collar workers (a poverty indicator) were positively related to the proximity to the waste facilities, whereas the percentage of professional and managerial workers (an affluence indicator) decreased with the proximity to the facilities. Communities with more pensioners were likely to be further away from the waste facilities, whereas the percentage of children under 15 years increased with the proximity to the facilities. These results were consistent with the findings of research from the other countries. However, disparities of significant magnitude were not observed for air pollution exposure and school accessibility. This research can be one first step for quantitative environmental justice analyses in Japan. Further work is needed to test this association either at the national level or in other Japanese settings, and future research should be expanded to cover a wide spectrum of environmental amenities and disamenities.

I. Introduction

The achievement of social equity as an outcome of environmental planning and decision making processes is being increasingly recognised as an important component of environmental policies in many countries[1)2)]. Originally, the concept of environmental justice was developed in the US, being largely driven by racial disparities in environmental quality. Since the 1980s, environmental justice has become a significant issue for the environmental movement[3)]. It was driven by the early findings of

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researchers such as Zimmerman[4] who found that waste disposal sites tended to be located in communities whose populations were mostly non-white or poor, resulting in a magnification of risks amongst those population groups. However, more recent work has expanded these concerns to incorporate disparities associated with more varied population characteristics, including age[5)6)]. In early works, environmental justice analyses also focused only on consideration of disamenities such as exposure to atmospheric pollution or hazardous facilities, but in recent years access to amenities, such as public parks or healthcare facilities has also been considered[6)7)]. Considering those trends, we adopt the definition of environmental justice as equal protection from environmental risks or equal opportunity to receive good environmental standards according to individual or population socio-demographic characteristics such as age and poverty (or affluence) level[8)9)].

Environmental justice studies, both of quantitative and qualitative ones, have been undertaken in many countries including the USA[10)11)], the UK[9)12)–14)], Holland[1)], Canada[15)16)], and New Zealand[2)17)]. Many of those studies found environmental injustices in a wide range of disamenities and amenities, such as proximity to hazardous waste sites, air pollution exposure, and accessibility to green spaces, in each context.

Japan also has sizable amount of literature on environmental justice analyses, and majority of them are based on qualitative research methods. Terada[18)], Fujikawa[19)] and Ikuta[20)] found that environmental disamenities such as industrial waste facilities, nuclear power plants, and polluting industrial factories, tend to be located in socially disadvantaged areas in Japan, and what social background caused such unequal distribution. They also described distress of victims of such injustice as well as how public movement emerged to oppose and reduce siting the disamenities.

These qualitative research contributed to clarify environmental injustice in Japanese context, yet very little quantitative works are available in Japan. Yasumoto *et al.*[21)] and Yasumoto *et al.*[22)] conducted quantitative environmental justice analyses in Kyoto using three dimensional urban models, and found distributive injustice of access to sunlight and view over the population. Yasumoto *et al.*[23)] statistically tested environmental justice in urban park accessibility in Yokohama, and found evidence of unequal distribution as well as casual mechanism which generates unequal distribution of park accessibility overtime.

There are several important reasons for conducting further quantitative environmental justice research in the Japanese context. Firstly, Pearce[24)] raised concerns that, since the majority of quantitative environmental justice research has been undertaken in the USA, it may be that the magnitude of environmental injustice assumed to be prevalent globally are biased according to this predominant geographical source. This research was undertaken therefore to provide new evidence in a very different cultural and environmental setting in Japan to that of the USA.

Secondly, Japan is a country where problems of poverty, social inequity and an aging society are increasing[25)26)]. These social trends may

generate serious magnitude of environmental injustice. As Pearce *et al.*[2] mentioned that environmental injustice also has potential to magnify health inequality between population. Additional quantitative environmental justice research, which focuses on a wide range of environmental amenities and disamenities, are therefore required to further understand the Japanese situation as well as particular equality implications.

In this case study, the relationships between social indicators and distribution of three environmental qualities are investigated: proximity to hazardous industrial waste management facilities, air pollution exposure, and accessibility of public elementary schools in the Japanese city of Yokohama. This suite thus comprises two environmental disamenities and one environmental amenity.

Waste management facilities were chosen because they have been well studied in other settings. These facilities have the potential to release pollutants into the land and ground water[27], and several studies found that proximity to them may be related to the risk of congenital malformations[28], and also negatively impact the mental health of those living nearby[29]. Furthermore there is much evidence from other settings that these sites tend to be disproportionately located in non-white or economically deprived communities[4)11)30]. In this research, the spatial distribution of waste management facilities for industrial waste requiring special control (i.e. special control industrial waste management facilities) is examined. The definition of special control industrial waste includes waste oil, waste acid, waste alkali, infectious waste, and other specified hazardous industrial waste such as waste PCB, specific sewage sludge, asbestos waste and particulate matter[31].

The other environmental disamenity examined in this study is exposure to air pollution. Poor air quality has been consistently related to mortality and morbidity from cardiovascular and respiratory diseases[32)33)], and several studies in other countries have reported disparities in air pollution exposure between different population groups. For example, Brainard *et al.*[5] reported a significant relationship between poverty, ethnicity and exposure to air pollution in Birmingham, England, and Pearce and Kingham[17] found that air pollution exposure was disproportionately high in less advantaged New Zealand populations.

The importance of population accessibility to amenities is widely recognised in city planning since access to places that people use regularly is strongly related to quality of life. Accessibility to elementary schools is a significant social issue, and schools are a major factor in determining the residential decisions of families[34]. Amongst other factors, good accessibility to schools provides safety for school children[35], and better opportunities for participating in after-school activities that use sports facilities. Nevertheless, relatively few environmental justice studies of accessibility schools have been undertaken. The only notable work is that undertaken by Talen[36] who found that children with lower socio-economic status had poorest accessibility to schools in rural areas of the US.

This study was conducted to test environmental justice of proximity to special control

industrial waste management facilities, air pollution exposure, and elementary school accessibility in Japan, a country where few past quantitative environmental justice studies are available. After we introduce methodology of environmental justice study of the three environmental qualities, results of statistical analyses are provided. We then conclude by demonstrating the findings, implications and caveats related to our approach.

II. Data and methodology

1. Scope of the study

The study area of this research is Yokohama city, which has the second largest population in Japan (Figure 1). This city is situated in Kanagawa prefecture next to Tokyo, the capital of the country, and the eastern boundary of the city is adjacent to Tokyo bay. Yokohama has been developed around large-scale industries, including manufacturing and tourism. Because Yokohama is a part of the Keihin region, one of the biggest industrial zones in Japan, since the 1940s environmental degradation has been amplified by the growth of industrial facilities, waste management plants or sources of air pollutants, causing much concern[37]. The city is known as a dormitory town for Tokyo, and the population increases annually (the total population changed from 2.8 million in 1980 to and 3.6 million in 2005), placing particular demands on the environment.

2. Social indicators of population

To define socially disadvantaged groups, we focused on population age and both poverty and affluence levels of communities. All data was extracted from Japanese Census records. Age

Figure 1 Study area (Yokohama city)

is an important determinant of vulnerability and life patterns of people[3)38)]. We focused on pensioners (those aged 65 years or more) since this group may be more vulnerable and susceptible to environmental risks[39)40)] due to their poorer health status and decreased mobility and social activity[38)]. Young children are also especially vulnerable to environmental risks[41)], and are the group with the need for good accessibility to elementary schools. Thus, we also investigated variations in environmental justice associated with the percentage of the population under aged 15. As indicator of poverty, we extracted the percentage of blue colour workers from the census. This group consisted of those classified as 'manufacturing process workers' and 'transport and machine operation workers'. Likewise, to measure the level of affluence in each community, the percentage of 'professional and technical workers and managers' was examined.

The social indicators of the population of the study area were extracted from the 2000 (population educational level) and 2005 (population age and job status) Japanese Census at the 500 m census grid cell level. 55 census grids were excluded from the sample because information on population characteristics was masked due to limited number of population.

3. Data of three environmental qualities

The distribution of the three chosen environmental qualities in the study area was measured within a Geographical Information System (GIS), and integrated with social indicators from the Japanese census to examine issues of environmental justice. All GIS analyses were implemented using ArcGIS 9.3 (ESRI Inc) using the methodologies described below.

To include positional data on special control industrial waste management facilities, facility address lists were obtained from Yokohama City Council. The lists identify each facility address at a building level (the survey year is 2006) which was then mapped in the GIS (Figure 2 (a)). To identify the characteristics of the populations proximal to each facility, buffer analysis was used[3)]. This analysis assumes people living in areas within pre-defined distance as proximate population to facilities, but the appropriate distance to delineate is often not well understood or tested[42)]. Sheppard *et al.*[43)] therefore suggest the application of several different buffer distances, and thus 500 m and 1 km buffers were generated here and the census grid cells that fell within them were identified. These distances have been frequently used in past studies[43)44)]. All census areas that were completely or partially enclosed by the buffers were defined as areas that were potentially at risk of contamination from the facilities.

The measure of air quality mapped was the distribution of outdoor nitrogen dioxide (NO_2) concentrations for the year 2005. NO_2 is one of the most prevalent air pollutants in urban areas[45)]. The main sources of man-made NO_2 are vehicle exhausts, such as those from automobiles and buses, and stationary sources such as industry[46)]. Exposure to NO_2 has been associated with a range of health concerns, in particular respiratory conditions, and there is evidence that the health effects may be greater amongst more vulnerable members of the population such as the elderly[47)] and young children[41)]. The data used for this analysis was extracted from the Research Report of Air Pollution pub-

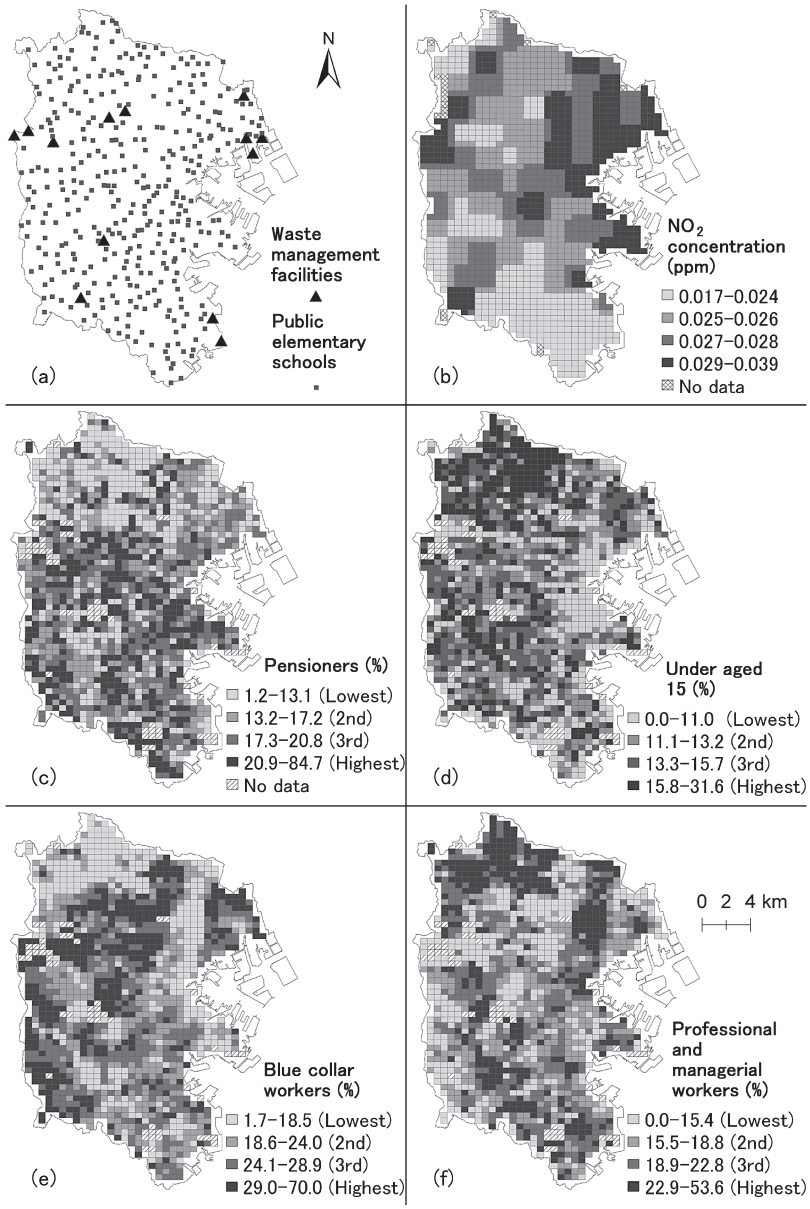

Figure 2 Spatial distributions of (a) special control industrial waste management facilities and public elementary schools; (b) NO_2 concentrations; (c) pensioners (%); (d) those aged under 15 (%); (e) blue collar workers (%); and (f) professional and managerial workers (%)

lished by the Environmental Planning Bureau of Yokohama City Council. In the survey for this report, Yokohama City was divided into 112 2 km×2 km cells and each cell had an air pollution monitor set around the centre. The concentrations of NO_2 (annual average NO_2, expressed in ppm) at each location were then measured, and for this study the mean NO_2

concentration for each census grid was estimated based on the value of the NO_2 cell that it fell within (Figure 2 (b)). NO_2 concentration for 18 census grids close to the city boundary were not available since those areas were excluded from 2 km grid based air pollution monitoring, and these were set to missing data.

The locations of most of public elementary schools were extracted from the Digital Map 2500 (Spatial Data Framework) product published by the Geographical Information Authority of Japan. The scale of this data was 1/2500, and survey year was 2005. A small number of schools were not represented on the Digital Map 2500 product and these were identified from a list of municipal schools obtained from Yokohama City Board of Education. Their locations were then identified on paper maps and manually added to the GIS.

In cases where schools had more than two buildings, a point in the centre of the school campus was identified. The resultant locations are shown in Figure 2 (a). To compute the accessibility of each school to each 500 m census grid, the road distance between the centre of each census grid and the nearest school point was computed in the GIS using a digital representation of the Yokahama road network also contained within the Digital Map 2500 product.

4. Analysis

The relationships between the three measures of environmental quality and each of the socio-demographic characteristics were investigated by classifying census areas into quartiles based on each indicator, and examining how the three measures varied across the quartiles. A set of logistic regression analysis were firstly fitted where the odds of being located within certain distance from waste facilities for each quartile. Next, average values of NO_2 concentration and measures of school accessibility across quartiles were computed. Finally, tests of trend among the quartiles were examined using Spearman's rank correlation analysis for all of the three analyses. All statistical analyses were undertaken in SPSS 16.0 (SPSS Inc).

III. Results

Figure 2 maps the spatial distribution of special control industrial waste management facilities, air pollution, public elementary schools, and social indicators of population in the study area. Four of the waste management facilities are located in the northeastern part of the city where the Keihin industrial region is situated. The highest concentrations of NO_2 are also observed in this area. The public elementary schools are more uniformly distributed throughout the city.

Table 1 reports the results from the environmental justice analysis. Where injustices were apparent their magnitude was generally greater for the 500 m buffer suggesting this distance may be more sensitive for environmental justice analyses measuring associations with population characteristics. The trend in odds ratios shows that communities with more retired residents are likely to be further away from the special control industrial waste management facilities. However, the percentage of the population aged 15 increased with proximity to waste facilities, although only for the 500 m buffer. Stronger evidence of injustice was

Table 1 Result of environmental justice analysis

Quartiles	500 m buffer from waste facility				1 km buffer from waste facility				NO_2 (ppm)	Distance to school (m)
	Within	Outside	OR	95% CI	Within	Outside	OR	95% CI		
Pensioners (%)										
Lowest	28	312	1		49	291	1		0.0265	
2nd	7	333	0.23	0.10–0.54	33	307	0.64	0.40–1.02	0.0266	
3rd	14	326	0.48	0.25–0.93	34	306	0.66	0.41–1.05	0.0266	
Highest	3	337	0.10	0.03–0.33	9	331	0.16	0.08–0.33	0.0256	
Trend			-**				-**		-**	
Under 15 (%)										
Lowest	8	333	1		29	312	1		0.0266	690
2nd	9	330	1.14	0.43–2.98	22	317	0.75	0.42–1.33	0.0262	689
3rd	17	323	2.19	0.93–5.15	41	299	1.48	0.89–2.44	0.0263	669
Highest	18	322	2.33	0.99–5.43	33	307	1.16	0.69–1.95	0.0261	705
Trend			+*				+ NS		-*	+ NS
Blue collar workers (%)										
Lowest	3	337	1		11	329	1		0.0267	663
2nd	6	336	2.01	0.50–8.09	19	323	1.76	0.82–3.76	0.0261	654
3rd	10	328	3.42	0.93–12.56	33	305	3.24	1.61–6.52	0.0259	697
Highest	33	307	12.07	3.67–39.77	62	278	6.67	3.44–12.92	0.0266	739
Trend			+**				+**		-NS	+**
Professional and managerial workers (%)										
Lowest	26	314	5.55	2.10–14.63	50	290	3.28	1.85–5.81	0.0265	722
2nd	13	327	2.66	0.94–7.56	34	306	2.11	1.16–3.86	0.0265	692
3rd	8	332	1.61	0.52–4.99	24	316	1.44	0.76–2.74	0.0261	659
Highest	5	335	1		17	323	1		0.0261	680
Trend			-**				-**		-NS	-NS

Lowest/highest Quartile=Least/most percentage of population characteristics
Within=number of census grid within buffer of special control industrial waste management facilities
Outside=number of census grid outside buffer of special control industrial waste management facilities
OR=Odds ratio 95%CI=95% confidential interval
Direction of trend (+ positive - negative)
**: P<0.01 *: P<0.05 NS: No statistical significance

apparent for blue collar workers, with more impoverished communities with high percentage of them being more likely to be located within the buffers. As may be anticipated, the opposite association with proximity was apparent for the percentage of professional and managerial workers in census grid cells.

Magnitudes in the variation of NO_2 exposure across the different social groups were very small although areas with the highest percentages of retired populations and children did experience slightly lower concentrations of pollution. Surprisingly the percentage of the population aged under 15 showed no association with distance to elementary schools. As schools are not needed by retired populations, accessibility was not tested in this group. The results do suggest however that communities with a high percentage of blue collar workers tend to have worse accessibility to public elementary schools, although magnitude of injustice was again small across quartiles.

IV. Discussion and conclusion

Since until now very little quantitative research on environmental justice has been done in Japan, this study was conducted to statistically test existence of injustice. Applying cross-sectional modeling of distribution of the three environmental quality metrics, this research provided some evidence of injustices in Yokohama, Japan. This was particularly so for the association between each job status and proximity to special control industrial waste management facilities. The percentage of children under 15 years also increased with the proximity to the facilities. These results support findings in other countries, such as the US, where often found disproportionate burden of environmental risk in socially disadvantaged communities[3)4)43)]. However, we also found that a high percentage of the elderly residents was negatively associated with proximity to facilities. No environmental injustices in air pollution exposure and school accessibility of any notable magnitude were observed between different social groups.

Despite of the strong evidence of injustice of proximity to waste facilities, it is important to remember that blue collar workers living nearby the special control industrial waste management facilities may enjoy other benefits which offset their poorer living environment, the most obvious being good access to workplaces in industrial areas.

There are several limitations to our study. The fact that our design was cross sectional means that it provides no information on the causal mechanisms that may underlie and injustice observed. Longitudinal studies which focus on time-dependent changes in environmental justice are needed for this[11)], and indeed several previous longitudinal studies identified that unequal distributions of political power between communities and problems with market mechanisms may be important. Pastor *et al.*[48)] suggested that poorer populations are disadvantaged because they lack the resources to resist the siting of environmental disamenities. If this is the case in Yokohama, careful re-examination of zoning laws and encouragement of public participation for socially disadvantaged populations may help. In addition, Been[49)] found that lower housings cost in environmentally disadvantaged areas attracts disadvantaged populations via move-in. If this is so then income redistribution programs, such as the provision of rent assistance for disadvantaged groups, may also have a play to role[49)].

Our analysis was based on residential location, and mobility patterns were not incorporated. In reality, people often move outside their home neighbourhoods for work, recreation or other purposes, and may thus experience different environmental risks or opportunities[5)]. It may be feasible to incorporate global positioning systems (GPS) into population surveys to capture people's travel patterns and incorporate them into framework of environmental justice studies[50)]. A further consideration is that the buffer approach we employed is a simplified method for calculating environmental associations as this approach assumes that the people within the buffer face an equal amount of risk or benefit[42)]. In reality patterns of exposure to of environmental and benefits will vary on a more

continuous scale, being related to factors such as wind and water flow direction, topographical characteristics and other environmental factors[3)51)]. Nevertheless, the extent to which distance from the facilities is related to the actual risk or exposure of a neighbourhood is yet to be determined[42)], and the sensitivity analysis we undertook suggests that a 500 m buffer may represent a suitable distance for detecting associations.

A further limitation is that our measure of access to schools did not consider quality. Student performance is often used as a measure of quality[52)], but information on test scores across public elementary schools was not available for the sample area. Moreover, these scores can themselves be associated with population demographic characteristics[53)] in ways in which the direction of causality is unclear. Therefore, we suggest quality is difficult to measure in an environmental justice context.

Although this study is a case study and the sample area is regionally limited, Yokohama is a well-known Japanese city situated next to the capital Tokyo, and hence this city could easily be considered a typical Japanese urban area in terms of geography and population. We found strong evidence of injustice in proximity to hazardous waste facilities in the city. Further work is needed to test this association either at the national level or in other Japanese settings, and future research should be expanded to cover a wide spectrum of environmental amenities and disamenities.

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横浜市を対象にした環境正義の計量分析
―社会的属性と環境の質との関係―

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米国やその他の西洋諸国と比べて、日本においては環境正義の計量的な実証分析はわずかしか存在しない。横浜市を対象にした事例研究を行うことで、本稿では居住者の社会的属性の分布と特別管理産業廃棄物処理場、大気汚染、そして公立小学校の分布との空間的関係を統計的に分析した。分析の結果として、ブルーカラー割合（貧困度の指標）が高い地域ほど特別管理産業廃棄物処理場と近接している傾向があり、一方で専門的・技術的および管理的職業の従事者割合（富裕度の指標）が高い地域ほどこれらの施設と距離が離れている傾向がみられた。また15歳未満の人口割合が多い地域も特別管理産業廃棄物処理場に近接している傾向があった。これらの結果は他の国々と同じように、日本の都市においても産業廃棄物処理場をめぐる環境の不正義が存在していることを示している。一方で大気汚染や小学校の近接性の配分に不正義はみられなかった。本稿は環境正義の計量的分析のファーストステップの一つとなりえるが、今後もその他の地域や環境の質を対象にしたさらなる研究の蓄積が望まれる。

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