land

MDPI

Article

Environmental Inequality in Peri-Urban Areas: A Case Study of Huangpu District, Guangzhou City

Jing Shen [1], Shaogu Wang [1,*] and Yuyin Wang [1,2]

[1] School of Geography and Planning, Sun Yat-sen University, Guangzhou 510006, China; shenjing@mail.sysu.edu.cn (J.S.); wangyy237@mail3.sysu.edu.cn (Y.W.)
[2] Kunming Urban Planning & Design Institute Co., Ltd., Kunming 650041, China
* Correspondence: wangshg6@mail2.sysu.edu.cn

Abstract: This research investigates environmental inequalities within Guangzhou's Huangpu District against the backdrop of rapid urbanisation and industrial expansion in Asia. This study identifies environmental hotspots, particularly in socially vulnerable areas characterised by high industrial density, using a vulnerability framework and analysing census and pollution data. Utilising satellite imagery, urban planning documents, and field research, we delve into the internal environmental conflicts arising from industrial land use. Our findings reveal how diverse stakeholders, guided by their rationales and interests, collectively contribute to spatial inequalities within a market-driven context. Importantly, we emphasise that environmental inequality transcends mere conflicts of interest among stakeholders and is fundamentally shaped by the prevailing market-oriented spatial development model in peri-urban areas. This model results in urban segmentation, socio-economic stratification, and an uneven distribution of environmental risks and resources. Our study advocates for a paradigmatic shift in China's peri-urban spatial development and the integration of environmental protection and social equity alongside economic growth. We recommend moving away from short-term speculative practices and promoting long-term, community-engaged urban renewal strategies that harmonise economic progress with improved living standards and environmental sustainability.

Keywords: environmental inequality; peri-urban areas; spatial development; Guangzhou

Citation: Shen, J.; Wang, S.; Wang, Y. Environmental Inequality in Peri-Urban Areas: A Case Study of Huangpu District, Guangzhou City. *Land* **2024**, *13*, 703. https://doi.org/10.3390/land13050703

Academic Editors: Monika Kopecká and Yangyi Wu

Received: 2 April 2024
Revised: 6 May 2024
Accepted: 13 May 2024
Published: 16 May 2024

1. Introduction

The logic of capital and growth-oriented spatial policies has driven the restructuring of urban spaces and the emergence of inequalities under the influence of globalisation and neoliberalism [1,2]. The rapid industrial expansion and evolution of urban planning in Asian cities have triggered the reshaping of the economic and spatial structures in the peri-urban areas of metropolises [3]. Driven by the capitalisation of land value and the impact of land supply systems, polluting industries often migrate from city centres to peri-urban areas, with impoverished communities bearing the brunt of these industrial pollutants [4]. These regions exhibit high population mobility, complex and diverse social structures, and significant differences among social groups and are also areas where spatial differentiation, social stratification, and environmental risk inequalities are most pronounced. This phenomenon profoundly affects the environmental well-being and social equity of residents, warranting in-depth exploration and attention.

Peri-urbanisation growth patterns, particularly in the Global South and exemplified by China, offer a distinct perspective for examining environmental inequality [5]. This process differs markedly from suburbanisation in Europe and North America, which is characterised by low-density and discontinuous expansion [6]. Instead, peri-urbanisation in these regions exhibits more dynamic and transitional features, with urbanisation occurring informally and in a fragmented way, leading to mixed zones that blend rural and urban attributes [7–10]. This unique urbanisation trajectory has been significantly influenced by

the joint development policies of the state and private sector, which through land acquisition and speculative development, have propelled the urbanisation of real estate. However, this has not been without consequence, as the mismatch between industrial expansion and real estate development has led to disparities in public services and quality of life [11]. Furthermore, the continuous influx of social capital has triggered spatial capitalisation in the peri-urban real estate market, exacerbating inequalities in the distribution of environmental resources based on economic power [10,12,13]. For instance, Mah and Wang [14] found that some of the most significant health risks from pollution are concentrated in the suburban areas of China, 'where agricultural and industrial activities intermingle, and infrastructure, institutional and governance capacity are weak'. Hossain and Huggins [15] highlighted how rapid industrialisation in Dhaka's outskirts has degraded the local living environment, with a surge in the demand for low-cost housing leading to the spread of slum-like settlements and impeding social advancement. Evidently, environmental inequality is not merely a simple aggregation of vulnerabilities based on demographic characteristics and external environmental factors but is rather a more complex phenomenon [4,16–19]. It involves the spatial shaping of residents' employment and residential behaviours [20,21], the spatial allocation of capital through the real estate market [22,23], and the collusion between government-led urban spatial expansion and functional restructuring oriented towards development [24,25]. Therefore, environmental inequality in the peri-urban areas of mega-cities is a manifestation of the coupling relationship between spatial restructuring dominated by economic benefits and the environmental health needs of different population groups [18,26]. An in-depth analysis of environmental inequality in peri-urban areas must be conducted to better understand the regional differences in urban environmental justice and enrich its theory.

This paper delves into the environmental inequality in Huangpu District, a peri-urban region of Guangzhou and one of China's major metropolises. The peri-urban areas of China's large cities are undergoing a transformation and expansion led by the state in response to the challenges posed by industrial expansion and environmental pollution. Huangpu District, situated in the peri-urban area of Guangzhou, is home to the city's largest municipal landfill and nearly an eighth of the city's polluting enterprises. This makes it an exemplary case for studying conflicts between environmental risks and the residential community. This study systematically investigates the spatial distribution characteristics of environmental inequality in Huangpu District using the community as the primary unit of analysis. The term 'community' is adopted to denote a neighbourhood within Huangpu District governed by a Residents' Committee, which serves as the grassroots unit of urban administration in China. Spatially, communities within Huangpu District are identified by the boundaries set forth by the Residents' Committees, which are reflective of the broader administrative and planning contexts. These boundaries are associated closely with various factors, including housing conditions, social characteristics, and land-use planning, which contribute to the environmental disparities experienced by the community. The quantitative identification of environmental inequality characteristics in space was achieved through the use of census data and data on polluting facilities in conjunction with vulnerability analysis methods. Furthermore, this research conducts an in-depth case study on the changes in industrial land use and its relationship with environmental conflicts. This study is based on satellite imagery, urban planning documents, and field research to reveal the historical and current phenomena of environmental inequality. This study aims to identify the mechanisms behind the creation of environmental inequality and its impact on residents' lives through an analysis of the interactions between different stakeholders. The findings of this research not only provide an empirical basis and strategic recommendations for environmental governance and urban planning in other peri-urban areas but also offer fresh perspectives and theoretical supplements to the predominantly Western environmental justice theory.

2. Literature Review and Analysis Framework

2.1. Environmental Inequality in Peri-Urban Areas

Geographers and urban planners observe that the phenomenon of urban expansion and peri-urbanisation has often led to increased environmental inequality in peri-urban areas [2]. In Western countries, some scholars focus on the environmental injustice differentiation brought about by urban spatial development between central and fringe areas [18,27]. Hochstenbach and Musterd [27] utilised residential mobility data from 2004 to 2013 in the urban regions of Amsterdam and Rotterdam to identify a trend of low-income households and movement to peri-urban areas, where increasingly poorer living environments are faced. Frenkel and Israel [18] conducted a case study in a medium-sized city and its suburbs within Israel's central metropolitan region, using diverse statistical methods to analyse data from 1063 sampled households. They found that suburbanisation is positively associated with social stratification, leading to low-income populations being confined to older, poorly conditioned suburban communities and, thus, facing worse living environments. Using census data, Boone, Fragkias, Buckley and Grove [16] and Sicotte [19] identified patterns of environmental inequality in Philadelphia and Baltimore, respectively, linked to residential and employment segregation and exacerbated by the fringe areas' growing role as an employment and industrial centre. Compared with Western countries, the urbanisation of peri-urban areas in Asian countries is driven by government policies and planning rather than gentrification, and thus, the process of environmental inequality is affected by policies such as land use and housing. Through an analysis of environmental policies and industrial relocation patterns, Zhang, Tao, Yue and Su [24] found that the Chinese government's prioritisation of the urban environment in the face of social pressures has led to increased spatial exclusion in the inner peri-urban regions, as they experience an influx in environmentally harmful facilities. In studies in Japan [22] and South Korea [28], after the renovation of old workers' communities, original residents were often forced to move the peri-urban areas due to the dual pressure of environmental degradation and rising rents. Relevant studies emphasise the joint role of both governments and markets. The urban–rural gap in government environmental law enforcement attracts industrial enterprises to rural areas to seek environmental shelter, and the land-based fiscal system exacerbates the unreasonable allocation of environmental resources [14,15]. Under the operation of market laws, polluting enterprises choose to intensify spatial barriers related to employment and housing with real estate development [22,24,28]. These studies recognise that during the process of peri-urbanisation and urban expansion, the structural changes in industrial and residential land use gradually transform into spatial changes in environmental risks and population, thereby affecting environmental inequality [13].

Recent scholarship has shed new light on the intricate spatial dynamics of environmental inequality in peri-urban regions [7,10]. First, Simon [13] and Follmann [10] emphasised that the development of peri-urban areas unfolds in a non-linear and heterogeneous manner across space and time, creating a gradient between the urban periphery and the rural hinterland. Spatially, this gradient manifests as a continuous influx of socio-economic capital, triggering incremental construction activities and escalating demand for resources such as land, water and a healthy environment [7,29]. Differences in socio-economic status lead to differentiated patterns of impact among residents, particularly in their residential and employment choices, which, in turn, lead to significant differences in environmental quality and levels of public services, creating a diversified spatial configuration of environmental inequality [30]. Temporally, this peri-urban gradient challenges the simplistic categorisation of the urban or rural, with contemporary rural peripheries potentially evolving into urban areas in the future with hotspots of environmental inequality shifting over time [31]. Consequently, the research emphasis should transition towards an in-depth examination of environmental inequality as an evolving process, with a particular focus on identifying key regions within the peri-urban gradient and the socio-economic and political–economic dynamics that drive these disparities [13].

The above findings suggest that the mechanisms for generating environmental inequalities in the spatial development of peri-urban areas involve the interplay of political and economic factors and changing urban conditions. Existing scholarship tends to focus on the analyses of quantifiable elements, such as population migration, economic exchanges and political affiliation. However, as Bartels [7] and Rajendran [8] pointed out, this content-focused approach to research can overlook particular historical trajectories, socio-spatial dynamics and cultural contexts. These overlooked narratives are crucial to grasping the distinctive environmental injustices confronted by diverse populations in the context of profound socio-environmental transformation in peri-urban areas. Consequently, this paper scrutinises the specific manifestations of the unequal distribution of environmental risks from spatial and social perspectives, which are embedded in broader socio-economic, political, and historical processes, using the case of Huangpu District, Guangzhou City.

2.2. Analytical Framework

The findings of the literature review indicate that it is crucial to examine the underlying power dynamics of environmental inequality among multiple entities, such as governments, businesses, and residents. By integrating these power relations into the spatial transformation processes of peri-urban regions, we can gain a more comprehensive understanding of the mechanisms through which environmental disparities emerge. Therefore, this study constructs an analytical framework for environmental inequality in the peri-urban areas of China's large cities based on the 'entity–process–mechanism' approach (Figure 1).

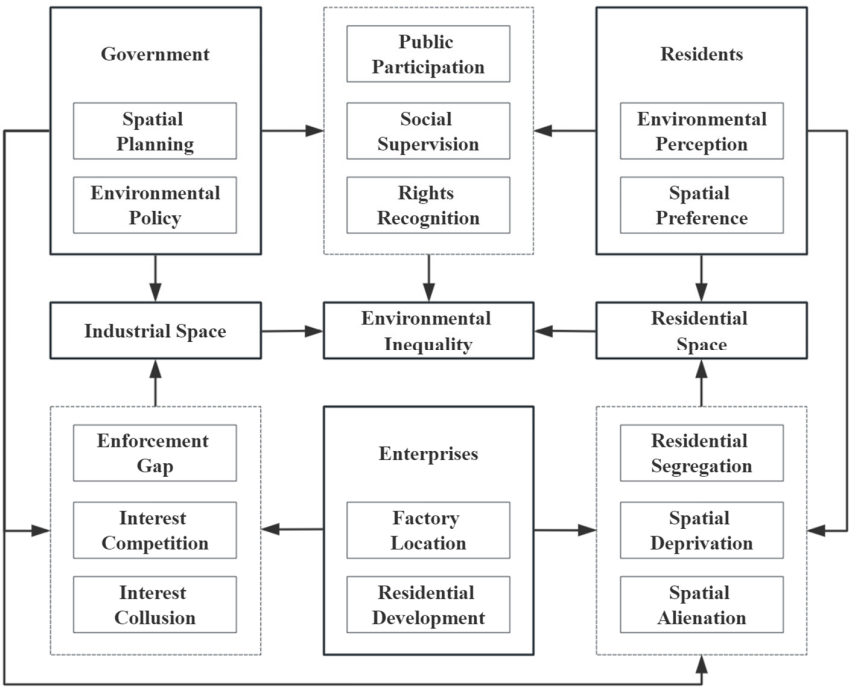


Figure 1. Analytical framework.

The government's impact on environmental inequality involves the following two aspects: spatial planning strategies and environmental regulation. First, as a local development model, it often adopts a spatial planning strategy centred on industrial concentration and transfers the environmental cost to other areas during the development process. Many studies have shown that social environmental problems generated by these issues continue to occur and can be remedied in peri-urban areas, which show a trend of outward diffusion that can further lead to spatiotemporal changes in environmental inequality [32–34]. At the same time, the government's spatial allocation of elements, such as factories, green spaces, and residences, which are usually based on economic benefits, results in an uneven distribution of environmental risks and resources. For example, it prioritises the arrangement of

environmental governance projects and funds in high-end communities and other areas with greater growth potential after environmental improvement, ignoring the urgent need for environmental improvement for ordinary residents or lower-class groups living in heavily polluted areas. Second, the government's impact on environmental protection and regulation is two-sided. The law enforcement gap between the central and the fringe areas may cause the fringe area to become a pollution refuge [24]. It also causes the environmental benefits of low-priced communities in the fringe area to be more vulnerable to infringement [25]. When dealing with environmental problems, the government may prioritise the environmental improvement of affluent communities [35]. These practices deepen the environmental differences between the city and the peri-urban areas.

The role of businesses is primarily reflected in the environmental performance of industrial enterprises and the residential development of real estate companies that result in occupational and residential segregation. Industrial enterprises, especially polluting ones, inherently face a contradiction between reducing environmental externalities and maximising profits during the production process [36]. This contradiction leads to a tendency for polluting factories to choose locations with lower land prices and labour costs. This practice not only exacerbates the local environmental burden but also affects the flow and distribution of local population, capital, and technology. For instance, Buzzelli et al. [37] reported that the re-planning of industrial space and the dispersion of industrial pollution to the suburbs make it more difficult for residents with higher status in the suburbs to avoid exposure to environmental risks. In the game of competing interests within the government, enterprises may use their contributions to the local economy as a bargaining chip to alleviate environmental responsibilities and evade environmental regulation. Capital and real estate developers construct an economically driven spatial segregation mechanism by manipulating the distribution of housing prices and job opportunities. This mechanism is not only reflected in the stratification of the housing market but also in the geographical distribution of job opportunities, thereby enabling groups with higher socio-economic status to obtain housing and employment opportunities in areas with better environmental quality.

The socio-economic status of residents can influence their perception and preference for environmental risks, thereby affecting their response to environmental risks. Residents with higher socio-economic status, such as the middle class, often have better educational backgrounds and more stable occupations, enabling them to focus more on environmental issues. The differences in environmental cognition and economic ability caused by class relations also have an impact on spatial differentiation and even form spatial segregation with the help of capital power. For example, Frenkel and Israel [18] pointed out that in the peri-urban areas of large cities, the differentiation of social space may lead to elite groups using their capital advantages to promote development that aligns with their environmental preferences, such as forming more homogeneous communities by building high-end residential areas. At the same time, the investment and construction of housing and public spaces by elite groups also intensify spatial deprivation. For instance, Kim and Woosnam [20] analysed the gentrification process in major South Korean cities and found that urban renewal leads to an increase in housing prices in residential areas, causing vulnerable groups to be excluded from areas with poor environmental quality. In addition, residents' perception of environmental justice is also influenced by resource allocation conditions and environmental background factors, forming differentiated homogeneous spaces. For example, in towns that make a living by recycling electronic waste, residents' rights to survival are tied to environmental risks, causing residents to prioritise economic benefits over health risks [38,39]. Meanwhile, highly educated people also tend to concentrate in high-pollution areas in the city centre due to the convenience of work and travel [40].

In peri-urban areas of large cities, superior location and living environments are scarce resources. The actions of the government, real estate developers, polluting enterprises and residents, although based on their logic and interests, collectively constitute a form of

collective behaviour that creates environmental inequality at multiple levels. All entities participate and maximise their various interests and needs in the process of shaping residential space [41]. The city government and real estate developers form a collusion of interests, implementing differentiated environmental governance policies, promoting the renewal of old communities, and other means to distribute and supply high-quality environmental resources in a differentiated manner [8]. The choice of housing by residents based on their income is the result of market forces. In the process of shaping industrial space, different social groups have differences in their ability to resist harmful industrial site selection and force polluting enterprises to eliminate pollution, causing external environmental costs to be shifted to the peri-urban areas and populations. The government, as the planner of environmental risks, has neglected the interests of fringe groups in the planning process and acts as a protector of risk producers, favouring corporate production in environmental decision making and blocking the public's right to participate in this [13,41].

3. Materials and Methods

3.1. Study Area

In the context of China, peri-urban regions are defined as the transitional zones between urban and rural landscapes, characterised by a mix of residential, industrial, and agricultural land uses. These areas are typically situated on the outskirts of metropolitan areas and are subject to rapid urbanisation and land-use changes [10]. The Huangpu District, situated in the eastern part of Guangzhou's central urban area, is a quintessential peri-urban area in China (Figure 2). It spans 484.17 km^2 and is inhabited by approximately 1.26 million residents as of 2020. The district's intricate demographic tapestry, evolving land use and industrial transformation render it a prime case study for scrutinising the spatial distribution patterns of environmental inequality within China's peri-urban contexts. First, the district's demographic complexity, shaped by urban expansion, encompasses a spectrum of communities, from indigenous populations to migrant workers and tech professionals, providing a microcosm of China's social restructuring. This diversity is central to the assessment of the distribution of environmental benefits and burdens, which is a core concern of environmental justice. Second, Huangpu's location at the urban–rural interface exemplifies the land-use tensions that define peri-urban China. The district's lower land values and the drive for expansion are leading to spatial conflicts, particularly regarding the mixing of residential and industrial zones. This can generate environmental externalities and socio-economic stratification, exacerbating environmental inequality.

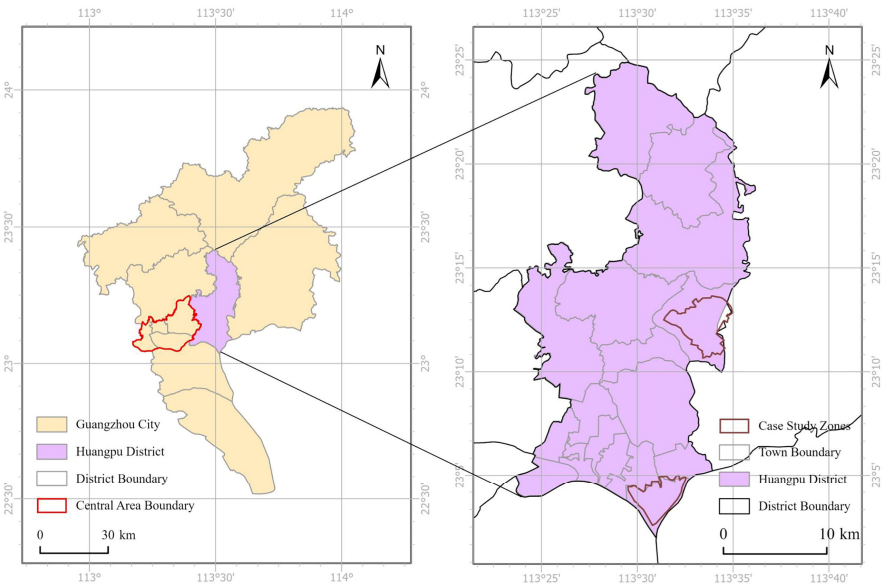


Figure 2. Location and administrative division of Huangpu District.

Furthermore, within Huangpu District, the transition from traditional industries to high-tech sectors and urbanisation initiatives has occurred in specific spatial contexts, leading to a complex interplay between the legacy of pollution and the rise of more sophisticated living environments. This transition has resulted in an uneven spatial distribution of environmental risks and benefits, contributing to the environmental disparities observed. The previous literature review showed that the environmental disparities evident in the spatial distribution of risks and benefits are not merely outcomes of industrial evolution; they are also manifestations of the intricate interplay between various stakeholders, each with their respective interests, including but not limited to environmental concerns. This interplay is a critical facet of environmental justice discourse and necessitates an in-depth qualitative inquiry into the multifaceted interests, power dynamics, and spatial patterns that shape the environmental landscape. Accordingly, the Guangzhou Economic and Technological Development District West Area (GEDA West Area) and the Yonghe Economic Zone (YEZ) within Huangpu have been selected for detailed qualitative analysis. These zones provide a microcosm of the district's industrial evolution and serve as emblematic examples of the broader challenges faced by peri-urban regions in balancing industrial growth with environmental sustainability and social equity.

The GEDA West Area, established in 1984, is the starting area of the Guangzhou Development Zone. Initially, it was positioned as an industrial base of Guangzhou city, with many industrial projects settling in, and the leading industries covered food, chemical industry, machinery, etc. With the continuous upgrade of industries, it gradually developed into a modern industrial park dominated by high technology, covering fine chemicals, food and beverages, new-generation information technology, biomedicine, intelligent manufacturing, and other industries.

The YEZ, developed after 2000, is an industrial park. Compared to the GEDA West Area, its geographical location is more peripheral, serving as an industrial park centrally planned by the government. Initially, the park mainly attracted polluting enterprises such as automobile parts manufacturing and food and beverage processing. Later, the government gradually adjusted the industrial structure, and the newly entered enterprises in the park were mainly high-end manufacturing, the electronic information industry, and the biopharmaceutical industry.

3.2. Data and Preprocessing

This research assesses environmental risks in Huangpu District by analysing data on environmental nuisance facilities and socio-economic demographics. Data on polluting industries, infrastructure and population characteristics are integrated, with communities as the fundamental unit for environmental inequality analysis. Population data are sourced from the 2010 and 2020 censuses and the National Geographic Information Public Service Platform, complemented by LandScan's population density figures. In the absence of detailed income data from the census, rent data from the Guangzhou Anjuke website and the Guangzhou Housing Rent Reference Price are used as income proxies. ArcGIS Pro 2.5.2 software is employed to transform community boundaries into spatial vector data, allowing for the estimation of 2020 community-scale population figures based on the 2010 community-scale and 2020 town-scale population data.

Environmental nuisance facility data were obtained from the 2022 National Pollution Permit Management Information Platform (https://permit.mee.gov.cn/permitExt/defaults/default-index!getInformation.action, accessed on 20 January 2023), supplemented by yearbooks and Shuijingzhu Universal Map's POI data. Industries are classified by emission intensity, with geocoding through the Baidu Map API enabling their spatial analysis within ArcGIS Pro 2.5.2 (Figure 3).

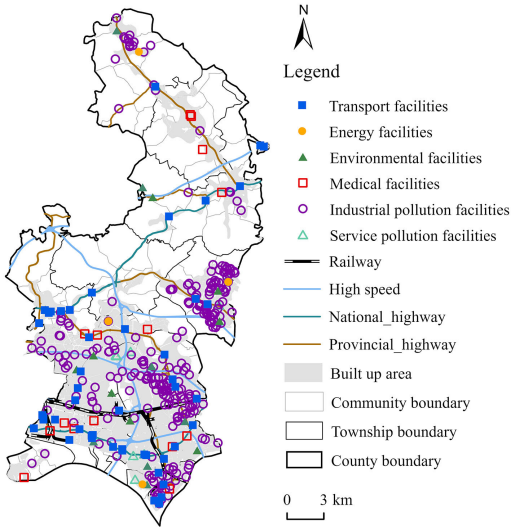


Figure 3. Spatial distribution of environmental nuisance facilities in Huangpu District.

3.3. Methodology

Cumulative Environmental Impact Assessment

The current method commonly used to comprehensively evaluate the environmental hazards and their unequal distribution caused by facilities with environmental risks within a region is known as the cumulative environmental impact assessment (CEIA) [42]. This approach calculates the social vulnerability index (SVI), environmental hazard index (EHI) and cumulative environmental hazard inequality index (CEHII) to reflect the concentration of vulnerable communities, the environmental impact produced by all pollution sources and the situation of environmental hazard distribution inequality, respectively. The method integrates the environmental impacts of polluting enterprises and those of transportation and environmental and medical sectors, along with the demographic conditions at the community level. The analysis conducted within ArcGIS Pro 2.5.2 spatially synthesises the multiple environmental and social pressures faced by communities with environmental inequality, offering a more comprehensive depiction of the current state of unequal environmental risk distribution in the region. It also provides a reference for the study of the causes of environmental justice and a practical basis for policy measures. Therefore, this study utilises this method to reflect the comprehensive impact of facilities with environmental hazards in Huangpu District, Guangzhou, which holds the concentration of vulnerable groups, and the current state of environmental hazard distribution inequality.

SVI: This index gauges the susceptibility of communities to environmental stressors by considering their sensitivity and adaptive capacity [43]. It integrates socio-economic variables, such as population density, household registration status, age distribution, educational attainment, and income levels [17,34,44] (Table 1). The SVI is calibrated using Z-scores to normalise the values, with negative scores indicating lower vulnerability.

Table 1. Indicators of social vulnerability.

Category	Variable	Indicator Description
Social vulnerability index	Population density	The population density of the community (people/km^2)
	Migrant	The proportion of non-local household registration in each community (%)
	Elderly	The proportion of the elderly over 60 years old in each community (%)
	Children	Percentage of population under 18 years of age in each community (%)
	Less educated	The proportion of adults who have not completed high school education in each community (%)
	Income	The inverse standardisation of the average unit rent in the community

EHI: This index measures the environmental hazards from nuisance facilities, with the categories listed in Appendix A. It calculates the weighted buffer zones around these

facilities, assuming reduced hazards with distance from the pollution sources [45]. Weights are assigned based on health protection distances and other criteria. The EHI score is calculated by multiplying each weight by the ratio of the covered area to the community area (Equation (1)), followed by Z-score standardisation after a 2.5% tail shrinkage treatment. Negative values indicate lower environmental hazards, while positive values suggest higher risks.

$$EHI_{Ci} = \sum_{i=1}^{n} w_i \left(\frac{A_i}{A_{total}} \right), \quad (1)$$

where EHI_{Ci} is the score of the EHI for each community, W_i is the weight assigned to different buffer zones, n is the number of buffer zones with different weights within the community, A_i is the area of the buffer zone covered within the community, and A_{total} is the total area of the community.

CEHII: The CEHII is derived from the geometric mean of the SVI and EHI, providing a composite measure of environmental inequality. A positive CEHII signifies substantial environmental inequity, with higher values indicating more severe disparities. The intercorrelations among SVI, EHI, and CEHII were examined using a two-tailed Pearson's test to deepen the understanding of environmental disparities.

Field Research and Interviews

This study embarked on a comprehensive field investigation, conducting in-depth, semi-structured face-to-face interviews within the Huangpu District of Guangzhou. The interviews took place from March 2023 to January 2024, aiming to shed light on the underlying causes and distinct features of environmental inequality prevalent in the area. A total of 53 interviews were conducted, ensuring a diverse representation of the community, including residents, workers, community committee members, and business proprietors. The sample spanned a spectrum of ages, genders, professions, and socio-economic statuses, with detailed demographic information provided in Appendix B. The interview content was recorded via note-taking and aimed to gather insights on the perceptions of environmental shifts, the weighting of environmental considerations in decisions regarding housing and employment, the level of awareness and opinions on governmental environmental policies, the operational challenges that enterprises encounter in environmental stewardship and corporate social responsibility, and the strategic decisions made by government officials in balancing environmental conservation with economic progress.

After the interviews, the research team conducted field assessments in critical areas of the Guangzhou Economic and Technological Development District West Area and Yonghe Economic Zone, complemented by neighbourhood inspections in March 2023. High-resolution satellite imagery from the Google Earth Engine was employed to analyse land use changes, focusing on the spatial and historical shifts within industrial and residential sectors. Notably, while the imagery's specific resolution was not detailed, its quality was high enough to allow for effective visual interpretation and mapping in ArcGIS Pro 2.5.2, which supported the identification of land use transformations. In tandem with fieldwork, official planning documents detailing regulatory and land use plans, including industrial zone delineations, were sourced from the Guangzhou Municipal Planning and Natural Resources Bureau. A thorough cross-analysis of these documents with the satellite imagery provided a detailed evolution of land use within the Huangpu District despite the absence of specific resolution data for the satellite images.

While the interviews were not quantitatively analysed due to the qualitative nature of the data, the consistency and prevalence of themes across the interviews were used to draw conclusions and identify patterns in the community's experiences and perspectives in relation to environmental inequality.

4. Results

4.1. Spatial Patterns of Environmental Inequality

The empirical analysis of this study uncovered critical characteristics of environmental inequality in peri-urban areas. Initially, the spatial distribution of social vulnerability, as

depicted in Figure 4a, indicates higher levels of vulnerability in the southern and northern villages of Huangpu District. Communities with heightened social vulnerability are located primarily in several villages in these regions, marked by dense populations, a significant proportion of low-income groups, and a prevalence of lower educational attainment. These attributes limit residents' capacity to cope with environmental risks and restrict their access to environmental resources and services.

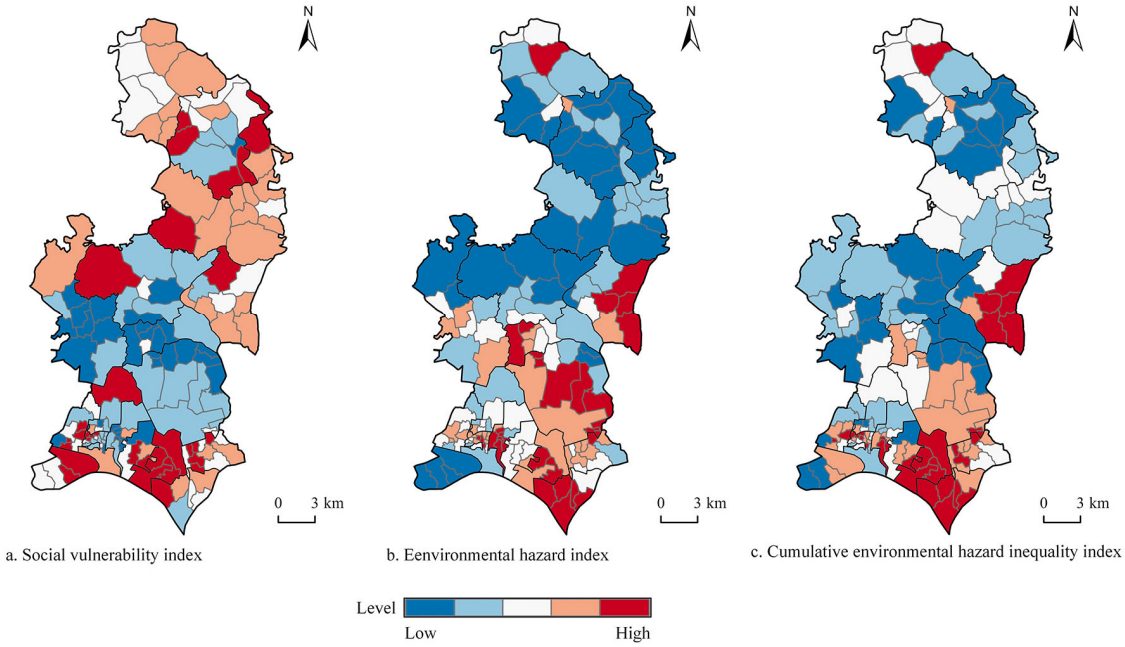


Figure 4. Distribution maps of SVI, EHI and CEHII in Huangpu District.

The geographic concentration of environmental hazards is also evident in the southeastern industrial parks and their surrounding areas, where a multitude of polluting enterprises and environmentally sensitive facilities are clustered (Figure 4b). As an industrial hub, the southeast region is home to numerous polluting industries and facilities, such as thermal power plants and sewage treatment plants. The operations of these establishments release substantial pollutants, severely affecting the quality of water, air, and soil and posing significant threats to the health and well-being of residents in its proximity. In contrast, the northern and southwestern parts of Huangpu District face reduced environmental hazards due to their removal from major pollution sources.

The cumulative environmental hazard inequality index (Figure 4c), derived from the overlay of social vulnerability and environmental hazards, pinpoints the primary concentrations of environmental inequality near the industrial parks in the central and southern parts of Huangpu District. These areas are not only rife with pollution facilities but also host vulnerable populations, including migrant workers and low-income individuals. Residents in these regions are subjected to heightened environmental risks and societal pressures. Communities in the northern and southwestern parts of Huangpu District benefit from a higher quality residential environment, with lower environmental risks and societal pressures due to factors such as higher income levels, better educational conditions, and a concentrated local population.

Pearson correlation coefficients were utilised to delineate the correlations between the SVI, EHI and CEHII within the region, as presented in Table 2. A significant finding was the absence of a significant correlation between the EHI and SVI, implying the absence of a direct link at the community level between communities with higher social vulnerability and increased exposure to environmental hazards. The correlation between SVI indicators and the EHI and CEHII indices indicated that communities with higher population densities and a larger proportion of migrants may experience a heightened

level of environmental hazards and inequality. The proportion of the elderly, children, education levels and income as indicators of SVI did not demonstrate a significant positive correlation with the EHI. Except for the proportion of children, these indicators showed a positive correlation with the CEHII at a 90% significance level, suggesting that communities with a higher proportion of these groups have increased social vulnerability and are more susceptible to environmental inequality. When examining the indices from the perspective of pollution facilities, no significant correlation was observed between any single environmental hazard facility and the SVI. However, except for medical facilities, other pollution facility indicators were strongly correlated with both the EHI and CEHII indices, indicating a potential common spatial distribution preference among these facilities. This preference does not have a significant association with social characteristics but contributes to the concentrated accumulation of environmental hazards in certain areas, leading to environmental inequality.

Table 2. Correlation analysis between SVI, EHI and CEHII.

Factor	SVI	EHI	CEHII
SVI	1	0.077	0.594 **
EHI	0.077	1	0.848 **
CEHII	0.594 **	0.848 **	1
Population density vulnerability index	0.316 **	0.372 **	0.468 **
Migrant population vulnerability index	−0.153	0.373 **	0.219 **
Population age vulnerability index (elderly)	0.480 **	−0.111	0.166 *
Population age vulnerability index (children)	0.093	−0.236 **	−0.141
Index of vulnerability of the population compared to education level	0.639 **	−0.069	0.284 **
Index of population with income vulnerability	0.593 **	−0.177 *	0.173 *
Environmental hazard index of traffic facilities	0.032	0.549 **	0.460 **
Environmental hazard index of energy facilities	0.077	0.542 **	0.478 **
Environmental hazard index of environmental facilities	0.033	0.620 **	0.518 **
Environmental hazard index of medical facilities	0.056	0.218 **	0.205 *
Environmental hazard index of polluting manufacturing industry	−0.009	0.500 **	0.399 **
Environmental hazard index of the polluting service industry	0.041	0.556 **	0.470 **

Note: * and ** refers to the statistical significance at 10% and 5%.

A comparison of the spatial distribution of the three indices with the correlation outcomes evidently shows that the differential spatial distribution of SVI, EHI and CEHII is connected to the distinct social, historical, and economic conditions of specific locales. Communities with heightened social vulnerability are predominantly concentrated in the older urban areas of the southern part of Huangpu District. These regions have undergone a transformation from industrial towns to modern urban areas, with the central areas now featuring high-rise residences while the peripheries remain as urban villages and old residential communities. The gradient in rent has resulted in communities located in more remote areas attracting a substantial migrant population, leading to increased population density and increased social vulnerability. The spatial concentration of environmental hazards is closely related to the industrial zones that the Guangzhou government planned during the urban expansion in the 1990s. These areas, which are geographically more distant from the city centre, are characterised by industrial concentration, high pollution emissions and a relative lack of green spaces and environmental mitigation facilities, thereby subjecting residents to greater environmental risks. These areas most severely impacted by environmental inequality often result from the compounding of social vulnerability and environmental hazards. Therefore, the industrial spatial layout in peripheral areas has resulted in an uneven distribution of environmental hazards and migrants, which is the root cause of environmental inequality. The two case study areas within this study are exemplary representations of such inequality and, as focal points of environmental inequality, necessitate more nuanced attention and research.

4.2. Case Analysis

This study used the CEHII to select two case study areas for empirical investigation and analyse the formation mechanism of environmental injustice in the peri-urban areas of large cities.

4.2.1. Case One: Traditional Old Industrial Area

The GEDA West Area's transition to a high-tech industrial hub marked a strategic pivot from traditional, pollution-intensive industries to modern sectors like biotechnology and smart manufacturing (Figure 5). This shift prompted a critical re-evaluation of environmental impacts, prompting the relocation or modernisation of over 200 polluting enterprises to address historical environmental inequality. The government's subsequent spatial planning initiatives have been instrumental in redressing these disparities. The government has sought to create a more harmonious living environment in the eastern region by strategically concentrating polluting industries in the western region and reconfiguring western residential areas for industrial use. This approach has not only improved economic efficiency but also enhanced the overall environmental quality since 1995. The clear demarcation of industrial and residential zones in the spatial development plan has mitigated the severe environmental exposure previously experienced by the area's primary residents, such as villagers and migrant workers. These coordinated measures have significantly lessened the environmental injustices prevalent in the area.

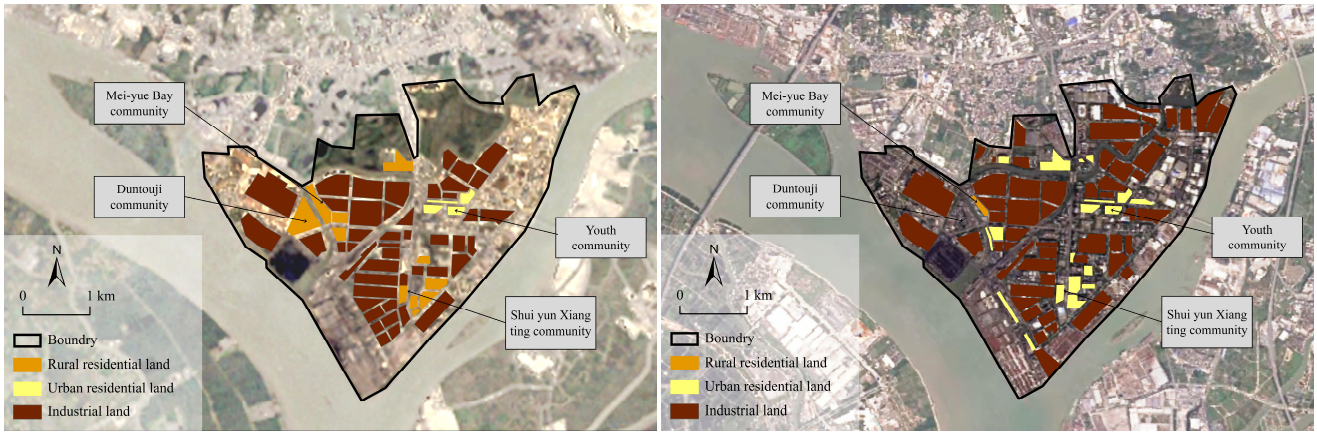


Figure 5. Distribution of industrial and residential land in the Guangzhou Economic and Technological Development District West Area in (**a**) 1993 and (**b**) 2020.

The spatial development strategies of the government at different times have influenced the distribution and harm of environmental risks. In the early stages, due to the presence of fewer residents compared to the city centre, industrial zones were planned, and polluting enterprises from the city centre were allowed to relocate there. However, a lack of reasonable planning led to the boundaries between residential and industrial areas becoming blurred, severely affecting the quality of life of the residents. Later, the government adopted a differentiated spatial restructuring strategy to improve the environmental impact on residents. The eastern area developed high-tech industries with less pollution through industrial replacement, and residential construction, supporting living facilities, was carried out through land replacement, significantly improving the living conditions of the residents.

In contrast, the western area retained heavily polluting and high-energy-consuming industrial enterprises that were important to its development, such as thermal power plants and steel mills. The government provided preferential resettlement policies and compensation schemes for the original villagers to alleviate the potential impact of these industrial activities on residents' health. However, inevitably, some old communities

remained and continued to suffer from environmental pollution, such as the Meiyue Bay community adjacent to the thermal power plant. The government's spatial planning h affects regional environmental risks. These spatial plans are the decisions made after weighing the pros and cons at different times, but a few vulnerable groups will always bear certain environmental harm, thus forming environmental injustice.

Industrial enterprises and real estate developers make differentiated environmental choices based on their characteristics. With the strengthening of environmental regulations, small and medium-sized enterprises choose to relocate due to rising governance costs, while those enterprises with good economic benefits negotiate with the government on the balance between environmental pollution and economic benefits. This balance often leads to the preservation of industrial facilities that are heavily polluted but have high economic value. For example, the Duntouji community, which is the most polluted, has many industrial and heavy chemical enterprises around, and consequently, its dust, noise, and odour pollution are severe. On average, 10 complaints about environmental pollution are received each year, which caused the government to finally decide to relocate the residential area. For developers, this area has huge market potential and value. They profit by participating in the transformation of old industrial buildings and urban villages in the area and building a batch of new residential projects, such as youth communities. However, the site selection of new residential projects often fails to fully consider its reasonable protection distance from the industrial area, causing some environmental conflicts. For example, in the high-rise residential area of Shuiyun Xiangting, located in the southern part of the area, residents have complained to the government, reflecting that they are often disturbed by the chemical gases and dust emitted by nearby factories, which seriously affects their daily life and health.

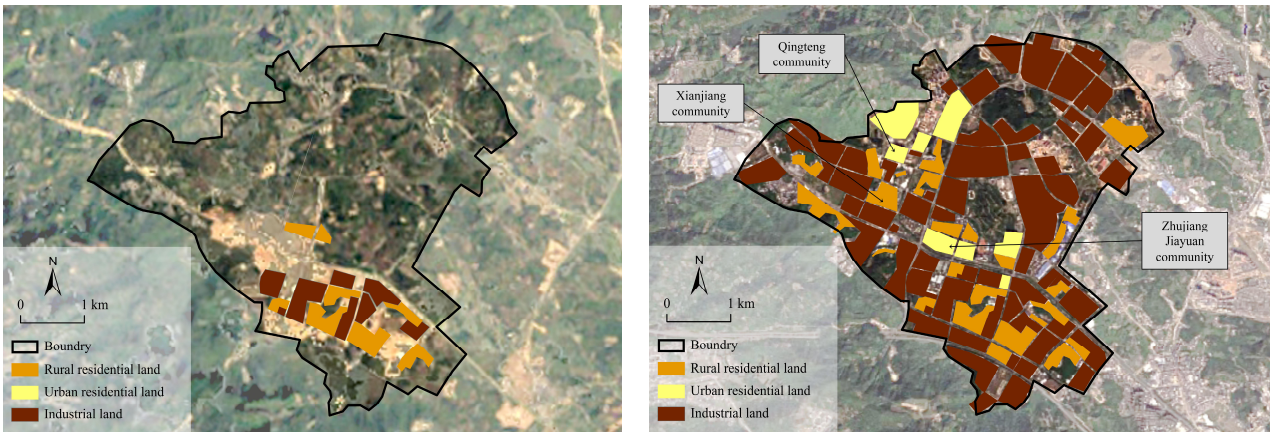
Residents and workers have a relatively weak understanding of environmental risks. Research has found that factory workers and residents near industrial areas bear the most severe environmental pollution impacts. Workers are willing to bear certain environmental risks due to their preference for low-cost housing and living close to their work, which objectively promotes many commercial housing projects to choose to develop near potential pollution sources, such as factories and docks. The middle class, which is composed mainly of middle and high-level managers and the technical talents of foreign-funded and local large-scale manufacturing enterprises, tends to live in well-planned, resource-rich living service areas. These areas are usually located far from industrial pollution sources, and their living preferences reflect the importance they attach to environmental quality. At the same time, the middle class plays a leading role in environmental awareness and actions, promoting capital and developers to invest in green spaces. Therefore, environmental justice is marginalised in the process of all parties pursuing economic benefits.

4.2.2. Case Two: Emerging Industrial Area

The Yonghe Economic Zone (YEZ) presents a study in contrast to the GEDA West Area, which initially attracted more polluting industries before transitioning towards high-end manufacturing and biopharmaceutical sectors (Figure 6). Despite these advancements, the spatial intermingling of enterprises and urban villages in the southern part of YEZ has led to increased environmental risks, predominantly for residents such as villagers and migrant workers. Early planning oversights resulted in a complex tapestry of small to medium-sized enterprises and urban settlements, exacerbating the environmental burden on these communities. In the northern expansion of YEZ, the government's attempts to spatially segregate industrial and residential zones have been undermined by the pervasive impact of corporate pollution, particularly air pollution. This impact has led to an ongoing struggle for environmental justice as the residents, encompassing the middle class, migrant workers and local villagers, continue to grapple with the adverse effects of industrial activities.

The government's spatial strategies at different times have shaped complex environmental justice issues by balancing economic benefits and environmental interests. In the early stages, the government faced the problem of industrial and residential areas being

mixed in the old industrial communities in the south. Through environmental regulation and renovation measures, land resources were released to alleviate environmental conflicts. These measures aimed to optimise spatial layout and reduce the direct impact of industrial activities on residents' daily lives. With the rapid expansion of the city, the formation of the northern industrial area reflects the government's control over the separation of industrial and residential land to reduce the potential impact of the industry on the living environment. However, some situations have occurred where the environmental rights and interests of residents are overlooked in the process of pursuing economic benefits from land development. For example, in the Qingteng community in the middle of the development zone, residents have long been affected by exhaust gas pollution caused by the production of these activities by the nearby fireproof material company, which has led to continuous complaints. This phenomenon reveals that the government may not have fully considered the environmental rights and interests of residents in the planning process, leading to the problem of secondary industrial and residential lands being arranged adjacent to each other. Overall, the government's spatial strategies have evolved, from the early renovation of old industrial areas to the planning of new industrial areas in the north, constantly adjusting to seek a balance between economic development and environmental protection. Despite these results, problems with the insufficient protection of residents' environmental rights and interests persist and need to be further optimised and improved.



(**a**) (**b**)

Figure 6. Distribution of industrial and residential land in Guangzhou Yonghe Economic Zone in (**a**) 1993 and (**b**) 2020.

The environmental behaviour of enterprises, based on economic considerations, affects environmental inequality. For polluting enterprises, their focus is on complying with the government's environmental management regulations rather than considering the environmental impact on residents. Enterprises often adhere to the government's environmental management regulations as the bottom line in their environmental behaviour rather than actively considering the impact of their activities on the quality of life of residents. Although the government regulates emission standards through environmental monitoring and information disclosure, residents in old industrial areas still face actual environmental pollution problems. They have expressed concerns about lax penalties, ineffective rectification, insufficient supervision, unreasonable monitoring, and a lack of transparency through various channels. The existence of these problems weakens the community's effective supervision and the checks and balances on corporate emissions. Real estate developers, in the pursuit of economic returns and market expansion, often do not adequately assess and avoid environmental risks, leading to new residential projects being created adjacent to potential pollution sources in industrial areas. This negligence in planning has not made full use of green belts and public facilities as a means of pollution isolation, exacerbating environmental inequality. As a result, elite groups occasionally face the impact of industrial

pollution despite relying on economic advantages to live in high-end communities. From the perspective of enterprises and developers, this behaviour reflects shortsighted business logic, that is, ignoring long-term environmental responsibilities and social welfare under the drive of maximising profits.

Significant differences in environmental awareness and preferences can be observed at the resident level, which can affect the living choices and environmental burdens of different groups. For residents of real estate communities in the area who have relatively high incomes, their communities are mostly located on the periphery of the development zone, or they rely on mountains to act as barriers to isolate industrial pollution to protect the living environment. However, migrant workers and villagers heavily affected by pollution live in urban villages in the industrial area, such as the Xianjiang community, and their living environment is also poor. The public's perception of social fairness is also related to their income level. Field research has found that compared to the old built-up areas, new real estate communities, such as the Zhujiang Jiayuan community, generate more environmental complaints each year. However, residents in the old urban villages, although they can also smell odours, do not show too much repulsion. This finding shows that middle-class residents with high-income levels have a stronger sense of their environment. In contrast, due to economic restraints, workers and villagers cannot choose residential areas and can tolerate minor pollution.

5. Discussion

This empirical study examines environmental inequality in Huangpu District, Guangzhou, and identifies its causes and patterns of development. Our findings are consistent with Rajendran's [8] perspective on India, which highlights the central role of industrial layout in shaping environmental inequality. However, this study extends the discourse using case studies to show how different actors within a market-driven spatial development model collectively contribute to environmental inequality through their different logics and interests. First, governments exert a significant influence on environmental contexts through spatial planning, as evidenced by the contrasting approaches observed within the Huangpu District. The GEDA West Area, characterised by an industrial legacy, is the subject of a government-led initiative to refine its spatial structure through community renewal despite its limited development potential. In contrast, the more remote location of the YEZ has attracted industrial and potentially polluting projects, reflecting speculative land use that can lead to social-spatial segregation and an unbalanced residential–industrial mix. Second, the activities of capitalists through their corporations have a profound impact on environmental justice. In the GEDA West Area, market forces have led to the relocation of polluting companies, while the YEZ attracts such companies with its cheap land and relaxed environmental regulations. In addition, developers responding to housing demands have often overlooked environmental risks by locating new housing projects near industrial polluters. This oversight, particularly evident in the YEZ's lack of synchronised residential and industrial development, exacerbates environmental inequality. Finally, residential environmental awareness and the recognition of environmental rights for marginalised communities are critical but often overlook aspects of environmental justice. Cultural differences and socio-economic pressures can distort environmental perceptions and priorities. For example, affluent communities in the northern part of the YEZ are more vocal about environmental issues, while residents in the mixed residential–industrial southern part are more resilient to pollution. Government spatial strategies, such as targeted environmental improvements in the GEDA West Area and speculative land development in the north of the YEZ, further influence these disparities. Therefore, the findings of this study support the conclusions of Bartels [7] and Rajendran [8], advocating that research on environmental inequality in the metropolitan periphery should combine a focus on practice with a broader analysis of processes or structures. This approach would allow for a more comprehensive understanding of inequality within the process of suburbanisation, thereby supporting the formulation of more effective policies and enhancing social participation. By recognising

the collective action of stakeholders and the spatial production of inequality, we could better address the complex dynamics of environmental justice in peri-urban regions.

Drawing on the views of Haase [41], this article argues that environmental inequality is not merely caused by conflicts of interest among subjects. The root lies in the market-led spatial development model and in the peri-urban areas, which provide the background and channels for these environmental conflicts. Against the backdrop of rapid urbanisation and industrialisation in China, the strategy of differentiated spatial production has led to a significant differentiation in urban space. This differentiation is manifested in the functional segregation of industrial and residential areas, the hierarchical distribution of socio-economic status, the unequal distribution of environmental risks, and the differentiation of resource allocation. Objectively, it creates a socio-economic environment for housing supply and replacement for major urban subjects, such as real estate developers, polluting enterprises, and residents. Environmental benefits have become assets that can be pursued and abandoned, providing channels for various subjects to participate in the distribution and collusion of environmental-related benefits. Therefore, the distribution of environmental risks is no longer simply attributed to the personal preferences of residents or the supply and demand relationship of the market, but the mutual mapping of the supply of different quality housing and the division of labour of social classes in space. More importantly, during the development process of the peri-urban areas, the government also changed from a political entrepreneur to a city manager. The new planning requirements conflict with the original urban space, leading to a situation similar to the 'patchy inequality' described by Kidokoro, Sho and Fukuda [22]. The government's gradual spatial development and governance, the gap in environmental law enforcement in different regions, and the speculative nature of community renewal and housing development have all led to the physical and social spaces of the peri-urban areas becoming more fragmented. Residents of different backgrounds are scattered in various corners of this space. There are high-quality communities equipped with high-quality public services that attract residents with strong economic capabilities, and there are worker communities near industrial areas with ageing infrastructure, leading to the development of spatial inequality at the micro level.

In the post-industrial era, the periphery of large cities in the East and West generally faces the problem of the unequal distribution of environmental resources among different social strata. This phenomenon reveals two different trajectories and intrinsic dynamics of urban development. In China, the development model of the periphery is mainly aimed at economic gains. The spatial distribution of environmental elements has become the basis for resource allocation among different interest entities. The coordination of interests between the government and enterprises plays a decisive role in the transformation of land use and the differentiation of living space. Environmental inequality comes more from the production end, the profit-seeking behaviour of the government, enterprises, and real estate developers. Firstly, the gradual spatial governance and industrial upgrading strategy often accompany the fragmentation of urban planning, which may lead to discontinuity and imbalance in the distribution of environmental resources. Secondly, housing diversification driven by real estate development may exacerbate social spatial isolation. In the peri-urban areas of Western cities, the environmental process is mainly dominated by capital operations, in which the preferences of the middle class and community participation play a key role. They tend to create more green spaces for residents with better economic conditions while promoting high-end social spaces. Environmental inequality comes from both the production end and the consumption end. Environmental improvement often accompanies rising house prices and social class restructuring, leading to the direct or indirect eviction of low-income groups. For example, the construction of urban green spaces such as High Line Park and Central Park not only enhances property values but also exacerbates the exclusion of low-income groups [46]. In addition, vulnerable groups such as the homeless, residents with low income, and people of colour suffer discrimination and exclusion in public spaces, exacerbating their 'displacement' phenomenon [47]. In general, the government-led industrial development history on the periphery of Chinese cities

not only restricts the large-scale intervention and transformation of capital but also leads to the social class needs of local elite groups not directly acting on the distribution of environmental resources. On the contrary, in the periphery of Western cities, the values and lifestyles of the middle class have a significant impact on the distribution of environmental resources. The change in environmental elements is not only the result of economic development but also part of the conscious social, spatial reorganisation and upgrading strategy of urban elite groups, thereby exacerbating the differentiation between social classes and the unequal distribution of environmental resources.

In the periphery of large cities in China, rapid urbanisation and industrialisation have brought about environmental inequality problems. To effectively respond to this, the urban development strategy urgently needs to turn to prioritising environmental protection and social justice. The government should go beyond the single pursuit of economic growth in urban planning and industrial layout decisions and incorporate the health and welfare of residents into its comprehensive considerations. This requires a comprehensive environmental risk assessment in land use and industrial layouts to ensure that the quality of life and environmental safety of residents are given priority. For the renovation of industrial areas with a legacy, adopting short-term speculative practices that may exacerbate social injustice and environmental degradation should be avoided. The renovation plan should be based on a long-term perspective and the principle of community participation, ensuring that the transformation of the industrial area not only brings economic growth but also promotes the improvement of residents' quality of life and environmental sustainability. In terms of pollution enterprise supervision, the government should build a strict environmental supervision framework, strengthen the monitoring of corporate emissions, and implement effective punishment mechanisms to ensure that enterprises do not sacrifice environmental quality and public health while pursuing economic benefits. In addition, the government should guide real estate developers to undertake social responsibilities and environmental ethics while pursuing economic benefits. By formulating green building standards and certification systems, developers can be encouraged to incorporate environmental protection designs and facilities into project development. For residents, especially marginal groups, the government should provide detailed environmental information and extensive participation channels. By establishing an environmental risk assessment and information disclosure platform, residents' awareness of the surrounding environmental conditions can be enhanced. At the same time, the government should enhance residents' environmental awareness and ability to participate through systematic education projects and community capacity-building activities, ensuring that they can actively speak and participate in the formulation and implementation of environmental policies.

6. Conclusions

In their in-depth exploration of environmental inequality in the urban peripheries of Global South cities, scholars have identified the limitations of traditional urban theoretical frameworks and city-centric environmental justice theories in explaining current challenges. While existing studies have acknowledged the multidimensional characteristics of environmental inequality in metropolitan peripheries, they often view these areas as the venues where environmental inequality occurs, neglecting the interactions and impacts among different stakeholders at the micro level. These insights are of particular importance for the development of urban peripheries in the Global South.

This study takes the peripheries of large Chinese cities as an example to consider the process of generating environmental inequality during the development of these areas. Through quantitative assessment, this research has identified the distributional characteristics and hotspots of environmental inequality in the peripheries of large Chinese cities, finding that industrial layout plays a key role in shaping environmental disparities. Case studies indicate that the reorganisation of industrial and living spaces in the periphery is a complex process involving multiple agents. Different agents, based on their own logic

and interests, objectively constitute a collective behaviour, leading to an inevitable trend of spatial production inequality under market conditions.

Future research needs to focus on the role of environmental facilities such as parks and greening in improving residents' welfare and consider cross-regional comparisons to reveal a wider range of environmental inequality phenomena. In addition, the further collection of micro-data to explore the interaction between socio-economic factors and environmental inequality and effective policy and social participation strategies is needed.

Author Contributions: Conceptualisation, J.S. and S.W.; methodology, Y.W. and S.W.; software, Y.W. and S.W.; validation, J.S., Y.W. and S.W.; formal analysis, Y.W. and S.W.; investigation, Y.W. and S.W.; resources, J.S.; data curation, Y.W.; writing—original draft preparation, J.S., Y.W. and S.W.; writing—review and editing, J.S.; visualisation, S.W.; supervision, J.S.; project administration, J.S.; funding acquisition, J.S. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the National Natural Science Foundation of China (Grant No. 42271181, 41871111).

Data Availability Statement: The raw data supporting the conclusions of this article will be made available by the authors on request.

Conflicts of Interest: Author Yuyin Wang was employed by the company Kunming Urban Planning & Design Institute Co., Ltd. The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Appendix A. Classification and Buffer Setting of Nuisance Facilities

Category	Content	Buffer Size	Buffer Weight
Transportation Facilities	Highways, Railways, National and Provincial Roads, Ports, Gas Stations	400, 8000, 1200	1, 0.5, 0.25
Energy Facilities	Thermal Power Plant (Cogeneration) and Gas Supply Plant	1000, 2000, 3000 [a]	
	Substations	100, 200, 300 [b]	
Environmental Facilities	Garbage Disposal Plants, Garbage Incineration Plants, Hazardous Waste Treatment	300, 600, 900 [c]	
	Sewage Treatment Plants	500, 1000, 1500 [a]	
Medical Facilities	Specialised Hospitals, General Hospitals, Traditional Chinese Medicine Hospitals	300, 600, 900 [d]	
Polluting Manufacturing Enterprises	Computer, Communication and Other Electronic Equipment Manufacturing and Other Lightly Polluting Industries	300, 600, 900 [d]	
	Automobile Manufacturing, Metal Products, Pharmaceutical Manufacturing and Other Moderately Polluting Industries	500, 1000, 1500 [a]	
	Food Manufacturing, Chemical Raw Materials and Chemical Product Manufacturing and Other Heavily Polluting Industries	1000, 2000, 3000 [a]	
Polluting Service Enterprises	Transportation, Warehousing and Postal Services, Residential Services, Repair and Other Services, Scientific Research and Technical Services and Other Lightly Polluting Industries	300, 600, 900 [d]	

Note: [a]. For heavily and moderately polluting industries, refer to the following standards: Technical guideline for derivation of health protection zone about fugitive emission of atmospheric harmful substances (https://openstd.samr.gov.cn/bzgk/gb/newGbInfo?hcno=0046CC3BABFD13DA98C1D06D47AE5FCA, accessed on 20 January 2023), Determination method of external safety distance for hazardous chemicals production units and storage installations (https://openstd.samr.gov.cn/bzgk/gb/newGbInfo?hcno=562DEE9A4FEB5EF7CE2DEF8A0345AE00, accessed on 20 January 2023); [b]. Research on the Guidance of Municipal Facilities Integration Planning Based on Protection Distance Analysis (https://wenku.baidu.com/view/c12ff2ec6e175f0e7cd184254b35eefdc9d315ce?fr=xueshu&_wkts_=1696853941496, accessed on 20 January 2023); [c]. Environmental Risk Assessment of Domestic Waste Incineration Power Plant (https://wenku.baidu.com/view/cdf56d631ed9ad51f01df2cc?fr=xueshu&_wkts_=1696853805281, accessed on 20 January 2023); [d]. For lightly polluting industries, refer to the following standards: Health protection zone standards for industrial enterprises by noise (https://openstd.samr.gov.cn/bzgk/gb/newGbInfo?hcno=DED38A54C68F8203C726CFEB07DCF5CE, accessed on 20 January 2023).

Appendix B. Basic Information from Interviewing Participants

Category of Interviewee	Number of Participants	Annual Family Income Range (RMB)	Number of Participants
Community Neighbourhood Committee	4	Below 100,000	21
Residents of Real Estate Communities	29	100,000 to 200,000	12
Villagers of Urban Villages	2	200,000 to 500,000	4
Tenants of Urban Villages	12	Above 500,000	2
Individual Businesses near Real Estates Communities	6	Unknown	14
Total	53	Total	53

References

1. Soederberg, S.; Walks, A. Producing and governing inequalities under planetary urbanization: From urban age to urban revolution? *Geoforum* **2018**, *89*, 107–113. [CrossRef]
2. Wei, Y.D.; Ewing, R. Urban expansion, sprawl and inequality. *Landsc. Urban Plan.* **2018**, *177*, 259–265. [CrossRef]
3. Brenner, N. *Implosions/Explosions: Towards a Study of Planetary Urbanization*; Jovis: Berlin, Germany, 2014.
4. Ma, C.B. Who bears the environmental burden in China-An analysis of the distribution of industrial pollution sources? *Ecol. Econ.* **2010**, *69*, 1869–1876. [CrossRef]
5. Ekers, M.; Hamel, P.; Keil, R. Governing Suburbia: Modalities and Mechanisms of Suburban Governance. *Reg. Stud.* **2012**, *46*, 405–422. [CrossRef]
6. Shaw, B.J.; van Vliet, J.; Verburg, P.H. The peri-urbanization of Europe: A systematic review of a multifaceted process. *Landsc. Urban Plan.* **2020**, *196*, 103733. [CrossRef]
7. Bartels, L.E.; Bruns, A.; Simon, D. Towards Situated Analyses of Uneven Peri-Urbanisation: An (Urban) Political Ecology Perspective. *Antipode* **2020**, *52*, 1237–1258. [CrossRef]
8. Rajendran, L.P.; Raúl, L.; Chen, M.; Guerrero Andrade, J.C.; Akhtar, R.; Mngumi, L.E.; Chander, S.; Srinivas, S.; Roy, M.R. The 'peri-urban turn': A systems thinking approach for a paradigm shift in reconceptualising urban-rural futures in the global South. *Habitat. Int.* **2024**, *146*, 103041. [CrossRef]
9. Singh, A.K.; Narain, V. Lost in transition: Perspectives, processes and transformations in Periurbanizing India. *Cities* **2020**, *97*, 102494. [CrossRef]
10. Follmann, A. Geographies of peri-urbanization in the global south. *Geogr. Compass* **2022**, *16*, e12650. [CrossRef]
11. Butsch, C.; Heinkel, S.-B. Periurban Transformations in the Global South and Their Impact on Water-Based Livelihoods. *Water* **2020**, *12*, 458. [CrossRef]
12. Israel, E.; Frenkel, A. Social justice and spatial inequality: Toward a conceptual framework. *Prog. Hum. Geogr.* **2018**, *42*, 647–665. [CrossRef]
13. Simon, D. Urban Environments: Issues on the Peri-Urban Fringe. *Annu. Rev. Env. Resour.* **2008**, *33*, 167–185. [CrossRef]
14. Mah, A.; Wang, X. Accumulated Injuries of Environmental Injustice: Living and Working with Petrochemical Pollution in Nanjing, China. *Ann. Am. Assoc. Geogr.* **2019**, *109*, 1961–1977. [CrossRef]
15. Hossain, M.A.; Huggins, R. The Environmental and Social Impacts of Unplanned and Rapid Industrialization in Suburban Areas: The Case of the Greater Dhaka Region, Bangladesh. *Environ. Urban. ASIA* **2021**, *12*, 73–89. [CrossRef]
16. Boone, C.G.; Fragkias, M.; Buckley, G.L.; Grove, J.M. A long view of polluting industry and environmental justice in Baltimore. *Cities* **2014**, *36*, 41–49. [CrossRef]
17. Son, J.-Y.; Lane, K.; Miranda, M.; Bell, M. Health disparities attributable to air pollutant exposure in North Carolina: Influence of residential environmental and social factors. *Health Place* **2020**, *62*, 102287. [CrossRef] [PubMed]
18. Frenkel, A.; Israel, E. Spatial inequality in the context of city-suburb cleavages–Enlarging the framework of well-being and social inequality. *Landsc. Urban Plan.* **2018**, *177*, 328–339. [CrossRef]
19. Sicotte, D. Diversity and Intersectionality among Environmentally Burdened Communities in the Philadelphia Metropolitan Area, USA. *Urban. Stud.* **2014**, *51*, 1850–1870. [CrossRef]
20. Kim, H.; Woosnam, K.M. Urban gentrification, social vulnerability, and environmental (in) justice: Perspectives from gentrifying metropolitan cities in Korea. *Cities* **2022**, *122*, 103514. [CrossRef]
21. Schaeffer, Y.; Tivadar, M.J.E.E. Measuring environmental inequalities: Insights from the residential segregation literature. *Ecol. Econ.* **2019**, *164*, 106329. [CrossRef]
22. Kidokoro, T.; Sho, K.; Fukuda, R. Urban suburbia: Gentrification and spatial inequality in workers' communities in Tokyo. *Cities* **2023**, *136*, 104247. [CrossRef]
23. Dai, J.; Lv, P.; Ma, Z.; Bi, J.; Wen, T. Environmental risk and housing price: An empirical study of Nanjing, China. *J. Clean. Prod.* **2020**, *252*, 119828. [CrossRef]
24. Zhang, C.; Tao, R.; Yue, Z.; Su, F. Regional competition, rural pollution haven and environmental injustice in China. *Ecol. Econ.* **2023**, *204*, 107669. [CrossRef]
25. Chen, Y.; Yue, W.; La Rosa, D. Which communities have better accessibility to green space? An investigation into environmental inequality using big data. *Landsc. Urban Plan.* **2020**, *204*, 103919. [CrossRef]

26. Ianoș, I.; Jones, R. Local aspects of change in the rural-urban fringe of a metropolitan area: A study of Bucharest, Romania. *Habitat. Int.* **2019**, *91*, 102026. [CrossRef]
27. Hochstenbach, C.; Musterd, S. Gentrification and the suburbanization of poverty: Changing urban geographies through boom and bust periods. *Urban. Geogr.* **2018**, *39*, 26–53. [CrossRef]
28. Han, S. Spatial stratification and socio-spatial inequalities: The case of Seoul and Busan in South Korea. *Humanit. Soc. Sci. Commun.* **2022**, *9*, 23. [CrossRef]
29. Narain, V. Whose land? Whose water? Water rights, equity and justice in a peri-urban context. *Local Environ.* **2014**, *19*, 974–989. [CrossRef]
30. Murakami, A.; Medrial Zain, A.; Takeuchi, K.; Tsunekawa, A.; Yokota, S. Trends in urbanization and patterns of land use in the Asian mega cities Jakarta, Bangkok, and Metro Manila. *Landsc. Urban Plan.* **2005**, *70*, 251–259. [CrossRef]
31. Simon, D.; McGregor, D.; Nsiah-Gyabaah, K. The changing urban-rural interface of African cities: Definitional issues and an application to Kumasi, Ghana. *Environ. Urban.* **2004**, *16*, 235–248. [CrossRef]
32. Musterd, S.; Hochstenbach, C.; Boterman, W. Ripples of structural economic transformation: The changing social geographies of Dutch metropolitan regions. *Appl. Geogr.* **2020**, *116*, 102151. [CrossRef]
33. Rüttenauer, T. Bringing urban space back in: A multilevel analysis of environmental inequality in Germany. *Urban. Stud.* **2019**, *56*, 2549–2567. [CrossRef]
34. Ma, J.; Liu, B.; Mitchell, G.; Dong, G. A spatial analysis of air pollution and environmental inequality in Beijing, 2000–2010. *J. Environ. Plan. Man.* **2019**, *62*, 2437–2458. [CrossRef]
35. Mitchell, G.; Norman, P.; Mullin, K. Who benefits from environmental policy? An environmental justice analysis of air quality change in Britain, 2001-2011. *Environ. Res. Lett.* **2015**, *10*, 105009. [CrossRef]
36. Brinkman, J.C. Congestion, agglomeration, and the structure of cities. *J. Urban. Econ.* **2016**, *94*, 13–31. [CrossRef]
37. Buzzelli, M.; Jerrett, M.; Burnett, R.; Finklestein, N. Spatiotemporal Perspectives on Air Pollution and Environmental Justice in Hamilton, Canada, 1985–1996. *Ann. Assoc. Am. Geogr.* **2003**, *93*, 557–573. [CrossRef]
38. Pellow, D.N. Environmental Inequality Formation:Toward a Theory of Environmental Injustice. *Am. Behav. Sci.* **2000**, *43*, 581–601. [CrossRef]
39. Wang, K.; Qian, J.X.; He, S.J. Contested Worldings of E-Waste Environmental Justice: Nonhuman Agency and E-Waste Scalvaging in Guiyu, China. *Ann. Am. Assoc. Geogr.* **2021**, *111*, 2165–2184. [CrossRef]
40. Padilla, C.M.; Kihal-Talantikite, W.; Vieira, V.M.; Rossello, P.; Le Nir, G.; Zmirou-Navier, D.; Deguen, S.J.E.r. Air quality and social deprivation in four French metropolitan areas—A localized spatio-temporal environmental inequality analysis. *Environ. Res.* **2014**, *134*, 315–324. [CrossRef]
41. Haase, A. Inequalities and Injustices of Urban Green Regeneration: Applying the Conflict Analysis Perspective. *Land* **2024**, *13*, 296. [CrossRef]
42. OEHHA, C. *Cumulative Impacts: Building a Scientific Foundation*; Public Review Draft; Office of Environmental Health Hazard Assessment: Oakland, CA, USA, 2010.
43. Turner, B.L.; Kasperson, R.E.; Matson, P.A.; McCarthy, J.J.; Corell, R.W.; Christensen, L.; Eckley, N.; Kasperson, J.X.; Luers, A.; Martello, M.L.; et al. A framework for vulnerability analysis in sustainability science. *Proc. Natl. Acad. Sci. USA* **2003**, *100*, 8074–8079. [CrossRef] [PubMed]
44. Zhao, X.L.; Zhang, S.F.; Fan, C.Y. Environmental externality and inequality in China: Current Status and future choices. *Environ. Pollut.* **2014**, *190*, 176–179. [CrossRef] [PubMed]
45. Sadd, J.; Pastor, M.; Morello-Frosch, R.; Scoggins, J.; Jesdale, B. Playing It Safe: Assessing Cumulative Impact and Social Vulnerability through an Environmental Justice Screening Method in the South Coast Air Basin, California. *Int. J. Environ. Res. Public Health* **2011**, *8*, 1441–1459. [CrossRef] [PubMed]
46. Loughran, K. Parks for Profit: The High Line, Growth Machines, and the Uneven Development of Urban Public Spaces. *City Community* **2014**, *13*, 49–68. [CrossRef]
47. Sotiriou, G.; Petropoulou, C. Socio-Spatial Inequalities, and Local Struggles for the Right to the City and to Nature—Cases of Urban Green Parks in Athens. *Land* **2022**, *11*, 1899. [CrossRef]