The environmental inequality of urban sound environments: a comparative analysis

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ABSTRACT

Sound has been researched as either an environmental pollutant with detrimental health effects or a restorative environmental resource with beneficial outcomes for well-being. However, the actual benefit or threat derived from an environmental resource differs according to socioeconomic factors. We performed a comparative analysis of 22 studies, with a focus on the methodologies used and the demographic and economic profiles of the cities they examined. The results suggest that lower socioeconomic position is associated with a higher exposure to noise. This paper highlights the lack of research on the environmental equality of restorative spaces; provides theoretical contributions to the literature, calling for consistent and reproducible techniques to enable comparisons between results; and presents some remaining questions that still need to be investigated.

INTRODUCTION

Environmental noise, defined as unwanted or harmful sound created by human activity [1], is a major pollutant in urban areas [2]–[4]. It can reduce the capacity for people to meet their basic needs (e.g. sleep, socialization), leaving them unsatisfied and with increased stress [5]. As well, environmental noise exposure often results in decreased health outcomes, in terms of both auditory and non-auditory health [3]. Noise control as an approach seeks to mitigate these negative health outcomes by limiting emissions from the source or sound levels at the receiver [2]. However, urban spaces are not limited to noisy acoustic environments with detrimental health effects. Indeed, high-quality sound environments can have positive health effects on psychological well-being [6]. Moreover, long-term annoyance and stress-related psychosocial symptoms are reduced for individuals who have access to quiet greenspaces [7].This suggests the need for a more nuanced approach to the urban sound environment, one that goes beyond the quiet-noisy dichotomy.

The soundscape approach presents an alternative to noise control with a focus on how sound environments are experienced. A soundscape is a construct that occurs when a person or people perceive the sounds of a place as they interact with them [8]. This interplay between person, place and activity affects the response the person has to the space, which in turn affords specific outcomes. These outcomes include place making, socialisation and

psychological restorativeness [8]. This suggests that in order to promote diverse outcomes, we must promote diversity in our sound environments [2]. As well, soundscapes can encourage beneficial outcomes in terms of health and environment [2]. Even just having access to quiet greenspace can reduce long-term noise annoyance and is furthermore associated with fewer reports of problematic noise [7]. High-quality sound environments can also provide opportunities for restoration. In this sense, sound can be a resource for users of a space that can provide enjoyment, respite and convey cultural values, as well as expand the range of experiences the space can afford. In promoting a diversity of sound environments, the soundscape approach is about more than bringing noise down below threshold levels. Instead, the focus is on ensuring that the noise generated by urban activity (e.g. traffic) does not dominate over dynamic and unique sound environments [2].

While these effects have been documented for broad populations, the burden on particular socioeconomic groups has received very little attention. The existing studies on the inequality of the exposure to noise are difficult to compare because of different methodologies (i.e. choice of acoustic indicator, statistical technique, noise source and socioeconomic factors). Moreover, the existing evidence is often conflicting e.g. [9], [10]. A review of studies from the WHO European region confirmed this, finding that the results were mixed across studies for the same socioeconomic factor and between socioeconomic factors [11]. Furthermore, the environmental inequality of sound as a resource is severely under-researched with just one known study to date that examines the correlation between socioeconomic status and access to quiet spaces [12]. The present paper reviews the literature on the environmental inequality of sound and attempts to reconcile the results of existing studies to provide an overview of the inequalities of noise exposure according to material (e.g. income), social (e.g. race) and demographic (e.g. age) dimensions. The discussion of these results highlights areas of future research within the soundscape and environmental justice frameworks.

METHODS

The scope of the literature for this study includes peer-reviewed articles that examine inequalities in the distribution of sound environments, whether framed from a noise or a soundscape perspective. All studies had to be published since 2000 in either English or French, and rely on commonly-accepted acoustic indicators. The literature search was performed using two strategies. The first involved a keyword search through four curated databases: PubMed, ProQuest Central, Scopus and Ovid. Where available, keywords were chosen from the database thesaurus in order to improve the precision of the search. Thus, the keywords used differed slightly between databases. Table 1 provides the keywords for each database search, as well as the number of returns and the number of initial selections. Citations for the selected documents were imported into Zotero, where relevant titles were selected and redundancies were eliminated. Figure 1 shows the number of articles obtained at each stage of the literature search process. The second strategy was to perform citation mining to find studies that did not come up during the keyword search, including forward citation mining using Scopus and Google Scholar.

Table 1: Queries conducted for each database and the number of results returned.

Database	Query	Date	Entries Returned	Selected
Ovid	(socioeconomic status/ or social status) AND (noise/ or noise abatement/ or noise pollution)	2020-06-15	269	18

Database	Query	Date	Entries Returned	Selected
	(socioeconomic status/ or social status) and (soundscape/ or restorative/ or quiet/ or quiet zone/ or vibrant/ or auditory perception/)	2020-06-19	14	0
Proquest Central	(MAINSUBJECT.EXACT("Noise") OR TI("noise exposure" OR "exposure to noise" OR "environmental noise") OR AB("noise exposure" OR "exposure to noise" OR "environmental noise")) AND MAINSUBJECT.EXACT("Environmental justice" OR "socioeconomic factors" OR "income inequality" OR "educational attainment")	2020-06-19	67	4
	(TI("soundscape" OR "restorative" OR "positive sound" OR vibrant OR quiet OR "quiet zone") OR AB("soundscape" OR "restorative" OR "positive sound" OR vibrant OR quiet OR "quiet zone")) AND MAINSUBJECT.EXACT("Environmental justice" OR "socioeconomic factors" OR "environmental equity" OR "income inequality" OR "educational attainment")	2020-06-19	374	1
PubMed	noise/adverse effects[MeSH Major Topic] AND "sociological factors"[MeSH Major Topic]	2020-06-19	39	1
	"sociological factors"[MeSH Major Topic] AND (soundscape)	2020-06-19	6	0
	"sociological factors"[MeSH Major Topic] AND (quiet)	2020-06-19	102	0
Scopus	(TITLE-ABS (noise OR noise W/2 exposure OR "environmental noise") OR INDEXTERMS ("noise pollution")) AND TITLE-ABS ("environmental justice" OR "environmental equity" OR "socioeconomic status" OR "income" OR "educational attainment")	2020-06-19	254	23
	TITLE-ABS(soundscape OR restorative OR “positive sound” OR vibrant OR quiet OR “quiet zone”) AND TITLE-ABS(“socioeconomic status” OR “socioeconomic factors” OR “environmental *justice” OR “environmental *equality”)	2020-06-19	109	1

The literature search process yielded a total of 22 papers. Most of these (N=21) looked at the environmental inequality of noise exposure, and because some papers reported more than one noise source there were a total of 24 individual studies. A single paper examined the environmental inequality of quiet zones.

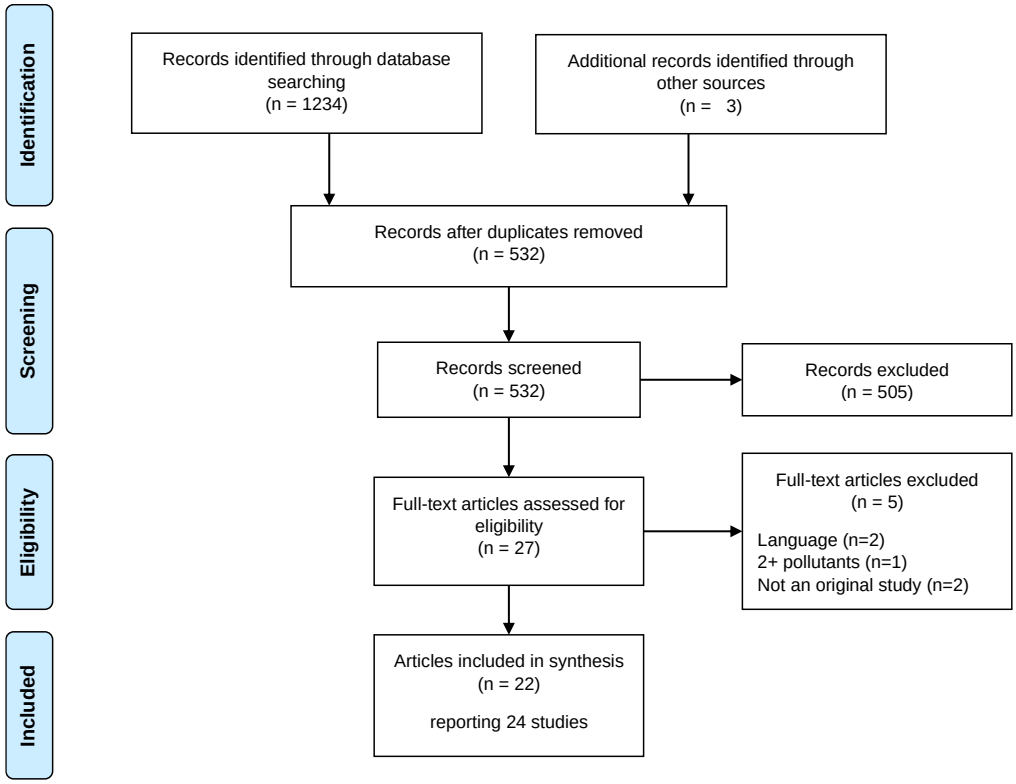

Figure 1: Number of articles retained during each step of the literature search process.

The methodology and findings of each study was recorded in an Excel spreadsheet to facilitate analysis. Finally, the recorded information was used to build theme-specific tables to guide the analysis. In particular, one table recorded the fifteen different socioeconomic factors examined and the significance of each in their findings. These factors were grouped into four larger categories: material (e.g. income), demographic (e.g. race), social (e.g. education) and other (e.g. health). Different variables were used across the studies to operationalize socioeconomic factors, some of which measure the specific factor in opposing ways. After uniformization, the results of the studies are reported in this paper such that a positive result indicates a greater exposure to noise for vulnerable populations.

RESULTS

Overview of socioeconomic factors used in the studies

Material factors were investigated in every study. In particular, income was the single most investigated factor in the reviewed literature, with 21 out of 24 studies. In the majority of these studies (65%), a statistically significant inequality was found (i.e. lower income is associated with higher levels of noise exposure). Proxies for material wellbeing (i.e. housing, employment and car ownership) were also investigated, though less frequently than income, and fewer statistically significant inequalities were identified.

Demographic factors were investigated in 19 out of 24 studies. Race/ethnicity and age were about equally represented here (14 and 13 studies respectively). Race/ethnicity had the highest number of statistically significant findings (n=26), most of them (n=23) suggesting that members of racialized communities face a greater exposure to noise than average. Age also had a high number of significant findings, though most of these (n=12) indicated that the

vulnerable community experienced less exposure to noise than average. Immigration status and sex were also investigated, though few significant findings were reported.

Social factors were investigated in just over half the studies (n=13), with few of these reporting significant findings. Seven studies used other factors, of which 6 use indices that combine a number of socioeconomic factors into a single variable.

Table 2: Socioeconomic factors examined in the 24 studies investigating inequality in noise exposure. Some factors were examined within a single study using multiple variables, allowing for one study to provide multiple significant results for a single factor. This is reflected in the final two columns where the percentage is the proportion of operational variables, not the proportion of studies. Variables in bold will be further investigated in this paper.

Socioeconomic factor	**Variables**	**Examples**	**# of studies**	**# of significant results**	
				Pos.	**Neg.**
Material factors (n = 24)	**Income**	Median income	21	18 *(65%)*	3 *(12%)*
	Housing	Overcrowding	12	8 *(29%)*	3 *(11%)*
	Employment status	Unemployment level	11	4 *(25%)*	0
	Car ownership	Number of cars owned	3	1 *(25%)*	0
Demographic factors (n = 19)	**Race/ethnicity**	Visible minority	14	23 *(74%)*	3 *(10%)*
	Age	Age (in years)	13	4 *(17%)*	12 *(52%)*
	Origin	Immigration status	7	1 *(9%)*	1 *(9%)*
	Sex	Sex	3	0	0
Social factors (n = 13)	**Education**	Years of education	11	3 *(19%)*	1 *(6%)*
	Family status	# of children	6	2 *(33%)*	0
	Social isolation	Proportion of non-Cantonese speakers	3	1 *(33%)*	0
	Social class	Social class	1	0	0
	Relationship status	Marital status	1	0	0
Other factors (n = 7)	Indices	Carstairs deprivation index	6	4 *(57%)*	1 *(1%)*
	Health status	Health status	1	1 *(100%)*	0

The sole study to examine quiet zones considered four socioeconomic factors: income (% of population with low income); age (% of population 65 or above); age (% of population 14 or less); and race/ethnicity (% of population that is a visible minority) [12]. The study found that the likelihood of access to quiet zones decreased with a higher proportion of low-income residents. Both vulnerable age groups (children and the elderly) were associated with a higher likelihood of access to quiet zones. The effect of race/ethnicity was not statistically significant.

Overview of sound sources and acoustical indicators

With one exception, the studies on noise exposure examined one or more specific noise sources (industrial, road, rail or air), or referred to environmental noise more broadly. Here, environmental noise refers to measured noise levels, where models are used to interpolate

missing data points. Table 3 identifies the noise source used in each study. Seventeen studies investigated transportation-related noise, of which 8 concerned noise from road traffic alone. A further 7 studies investigated road noise in combination with other noise sources (e.g. air-traffic noises). Five studies examined environmental noise more globally. The remaining study that did not examine noise sources or environmental noise instead asked participants to evaluate the perceived noise level near their homes through a large-scale questionnaire.

Table 3: List of reviewed studies with the acoustic indicators and noise sources used in each.

Continent	Study	Long-term energetic			Continuous	Statistical		None	Noise source				
		L_{dn}	L_{den}	L_n	L_{Aeq}	L_{50}	L_{10}		Air	Road	Rail	Ind.	Env.
Asia	**[13]**						X			X			
Subtotal (Asia)							1			1			
Europe	**[14]**		X							X			
	[15]				X				X	X			
	[16]		X							X			
	[10]		X							X			
	[17]							X					X
	[18]		X						X	X	X		
	[19]		X	X									X
	[20]				X				X	X	X		
	[21]		X							X	X	X	
	[22]		X							X	X	X	
Subtotal (Europe)			7	1	2			1	3	8	4	2	2
North America	**[23]**	X							X				
	[24]			X						X			
	[25]		X							X			
	[26]					X	X						X
	[27]				X				X	X			
	[28]				X				X	X			
	[9]				X								X
	[29]	X							X				
	[30]				X					X			
	[12]		X						X	X			
Subtotal (N.A.)		2	2	1	4	1	1		5	6			2
Total		2	9	2	6	1	2	1	8	15	4	2	4
		13			6	2		1					

The studies reviewed use a wide range of methods to operationalise noise exposure, both in terms of the acoustic indicators and methods for determining region-wide noise level. The acoustic indicators are grouped into main categories of energetic indicators (with or without corrections for specific time periods) and statistical indicators. Long-term energetic indicators corrected for the time period (L_{dn}, L_{den}, L_n for day/night, day/evening/night and night periods respectively) were most frequently used. Other energetic indicators include equivalent continuous levels over a certain duration ($L_{Aeq,T}$). Two studies reported the statistical L_{10} indicator, once in combination with L_{50}. L_T indicators provide the sound level that is exceeded during T% of the measurement time, with L_{10} being used as an indicator of emergence.

The study on the equality of sound examined access to quiet zones, operationalized as spaces with a maximum noise level of 55 dB(A) and a minimum lot size of 1000 m^2. Models of road and air traffic noise were used to calculate sound levels in L_{den} values, against which land-use maps were compared to identify the quiet zones.

DISCUSSION

This paper extends the review done by Dreger et al. [11] who found that their studies presented contradictory results, both within and between socioeconomic variables. We include studies from North America (Canada and the United States) and Hong Kong, as well as the European Union covered in the previous study. Moreover, this review examined 24 noise exposure studies over 21 papers, providing an opportunity where socioeconomic variables were repeated across studies. In doing so, we provide consolidated evidence that vulnerable or marginalized groups are overexposed to noise.

Socioeconomic inequalities of noise exposure

Consistent with Dreger et al. [11], we found that studies investigating material factors, especially income level, suggest an inequality wherein groups with lower material wellbeing are exposed to higher levels of noise. From a public health perspective, this might suggest that lower income populations have a double vulnerability problem in that they are both more susceptible [31] and more exposed to noise.

Future research should examine how environmental inequality along the material dimension works within different theoretical models. Some models suggest that noisy activities locate in already poor neighbourhoods, whether because of a reduced need for compensation (Coase theorem) or due to a perceived low propensity for collective action. Most models provide some form of economic agency to low-income households, even if they are not all able to exercise it adequately. The invasion-succession model and the push-pull model both suggest that the presence of noisy activities would drive out high-income households. However, in the push-pull model, the presence of a noisy activity is seen as a benefit for low-income households in that it lowers housing costs. Moreover, it is unclear how noise itself is viewed by low-income individuals. Further research is needed to position income as a factor in determining dread risk and unknown risk, in line with psychometric risk theory. The extent to which low-income individuals rate risk from noise on the dread and familiarity (unknown) axes can inform us about how they view noise.

The results for demographic factors across the studies are more mixed, both across and within individual factors. For one, racial or ethnic status was found to be a significant predictor of increased noise exposure in 11 studies. Only three studies found that racialized groups were underexposed to noise [28], [29], and in all three cases at least one other racialized group in the same study experienced an overexposure to noise. For example, Collins et al [28] found that Indigenous groups in the continental US were underexposed to road traffic noise,

though this was likely due to Indigenous Americans living mostly in rural communities. This suggests that environmental racism is a very real problem in the context of noise exposure.

Significant results were also found for age, though the directions of the correlations were mixed across the studies. Most results suggest that children are generally underexposed to noise, as in [17], [19], [22], [24], [25], [30]. This is in contrast with the situation for the elderly, where the significant results were roughly evenly divided between underexposed (see [16], [24], [28]) and overexposed (see [13], [17], [19], [22], [27]).

Further research is required to better understand how political and social processes influence the situation of environmental racism described by the literature. In other words, to what extent do the inequalities in the distribution of noise for racialized communities represent procedural injustices? As well, it is unclear how a lack of recognition and authority in public discourse compound problems of procedural injustice for racialized communities when it comes to noise exposure.

Theoretical models within the environmental justice literature suggest potential frameworks for understanding environmental racism. The pure discrimination model holds that people have racist motives and derive some benefit from siting noisy activities in neighbourhoods that have a higher percentage of racialized or ethnic communities. This assumes an intentional racism, however, which is difficult to establish through research [32]. Recognition is a critical element in enabling collective action and political parity [33], [34], suggesting that a theory of collective action provides a possible framework for understanding how siting decisions contribute to environmental racism. As well, it removes the need for intentionally racist motivations.

Social factors were the least investigated in the literature, even when the category includes education (which is also connected to material well-being). Moreover, social factors were not generally associated with an overexposure to noise.

Socioeconomic inequality of access to quiet

The study by Delaunay et al. [12] on inequality of access to quiet zones found that low income was associated with an overexposure to noise. As well, their mixed effects model showed that access varied greatly according to neighbourhood. Comparing with Carrier et al. [24], [25], we note that this suggests that low-income individuals are both overburdened by noise and have less access to quiet spaces that can be used to cope with noise problems. Despite the importance of this study, it narrowly defines a quality soundscape as having low decibel levels – 55dB(A) or lower – and greenspace. The soundscape literature promotes the idea of a diversity of soundscapes, rather than eliminating noise [2], [35].

Moreover, the relationship between high-quality, health-promoting sound environments and environmental equality is complex. While additional greenspace for socioeconomically vulnerable populations can be beneficial for health outcomes, these same socioeconomic factors mediate the use and acceptance of greenspace [32]. Gender, race and age all play a role in the perception and conceptualisation of greenspace. Greenspace exists in a social context where regulation, policing and gentrification lead to contestation and conflict between groups over the use and appropriation of space, both public and private. Thus, gender, race and age are all factors that should be considered when researching and promoting the health benefits of high-quality soundscapes.

Effect of methodology choices

The reviewed studies were mostly large-scale observational studies that examined exposure or access to quiet space from the place of residence only. In general, interaction effects between socioeconomic factors are not explored. Moreover, potential noise exposure at work

or during commute times was not considered in the studies. Similarly, Delaunay et al. [12] did not examine the availability of quiet spaces for employees to escape occupational noise. Flamme et al. [36] found gender and occupational differences in noise exposure at the workplace, suggesting that measures of daily exposure are important. Indeed, Dreger et al. [11] highlight that ignoring the workplace could result in an underestimation of the socioeconomic inequalities of noise exposure.

There is no consensus in the literature around the use of acoustical indicators and statistical methods to investigate relationships across variables. This review suggests that, to some extent, the choice of acoustic indicators appears to be informed by established practice for the city/region in which the study is being carried out. European studies tend to use long-term indicators, more specifically L_{den}, where the European Noise Directive has mandated the creation of noise maps using these indicators. In contrast, North American studies were more likely to use the L_{Aeq}, uncorrected for time of the day, commonly used in noise by-laws on this continent.

Reconciling the studies is made more challenging by their focus on different noise sources. Kruize et al. [18] provide some potential evidence that noise source may inform the extent of the existing inequalities. They found that road traffic noise is experienced more similarly across income levels than rail and air traffic noise. Future directions include a proposed study to directly compare the inequalities found for road traffic noise with those found for environmental noise, when using the same reference population data.

CONCLUSION

This review of observational studies suggests that certain socioeconomic groups are overexposed to noise. This could lead to a double burden in that these groups are either marginalized within society, more vulnerable to the health effects of noise, or both. The limitations of the existing research suggest some avenues for future research. One such avenue is to examine multiple socioeconomic factors for any interaction effects. In order to compare across studies, we need to better understand what effect choosing particular noise sources has on the outcome of inequality studies. However, this will only improve our understanding of noise exposure at home. Thus, future research should also investigate possible inequalities in day-long exposure to noise, specifically exposure in the workplace and when commuting.

More broadly though, there are important methodological limitations to observational studies that can be mitigated using a range of research methodologies. In line with the soundscape approach, mixed methods should be used to understand the lived experience. In this sense, future research should complement existing observational studies by examining different individuals' exposure to noise and how they use their sound environments to build coping strategies (where these exist). This also allows researchers to move beyond a quiet space that is defined primarily by low decibel levels, to also consider dynamic and eventful sound environments that might nonetheless support positive health outcomes.

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REFERENCES

[1] European Union, Directive 2002/49/EC of the European Parliament and of the Council of 25 June 2002 relating to the assessment and management of environmental noise. 2002, pp. 0012–0026.
[2] A. L. Brown, 'Soundscapes and environmental noise management', Noise Control Engineering Journal, vol. 58, no. 5, pp. 493–500, 2010.
[3] M. Basner et al., 'Auditory and non-auditory effects of noise on health', The lancet, vol. 383, no. 9925, pp. 1325–1332, 2014.
[4] J. Kang et al., 'Ten questions on the soundscapes of the built environment', Building and Environment, vol. 108, pp. 284–294, 2016, doi: 10.1016/j.buildenv.2016.08.011.
[5] T. C. Andringa and J. J. L. Lanser, 'How pleasant sounds promote and annoying sounds impede health: a cognitive approach', International Journal of Environmental Research and Public Health, vol. 10, no. 4, Art. no. 4, Apr. 2013, doi: 10.3390/ijerph10041439.
[6] F. Aletta, T. Oberman, and J. Kang, 'Associations between positive health-related effects and soundscapes perceptual constructs: A systematic review', International journal of environmental research and public health, vol. 15, no. 11, p. 2392, 2018.
[7] A. Gidlöf-Gunnarsson and E. Öhrström, 'Noise and well-being in urban residential environments: The potential role of perceived availability to nearby green areas', Landscape and Urban Planning, vol. 83, no. 2, pp. 115–126, Nov. 2007, doi: 10.1016/j.landurbplan.2007.03.003.
[8] A. L. Brown, T. Gjestland, and D. Dubois, 'Acoustic environments and soundscapes', in Soundscape and the built environment, J. Kang and B. Schulte-Fortkamp, Eds. CRC Press, 2016.
[9] L. M. Dale, S. Goudreau, S. Perron, M. S. Ragettli, M. Hatzopoulou, and A. Smargiassi, 'Socioeconomic status and environmental noise exposure in Montreal, Canada', BMC Public Health, vol. 15, no. 1, 2015, doi: 10.1186/s12889-015-1571-2.
[10] S. Havard, B. J. Reich, K. Bean, and B. Chaix, 'Social inequalities in residential exposure to road traffic noise: An environmental justice analysis based on the RECORD cohort study', Occupational and Environmental Medicine, vol. 68, no. 5, pp. 366–374, 2011, doi: 10.1136/oem.2010.060640.
[11] S. Dreger, S. A. Schüle, L. K. Hilz, and G. Bolte, 'Social inequalities in environmental noise exposure: A review of evidence in the WHO european region', International Journal of Environmental Research and Public Health, vol. 16, no. 6, 2019, doi: 10.3390/ijerph16061011.
[12] D. Delaunay, P. Apparicio, A.-M. Séguin, J. Gelb, and M. Carrier, 'L'identification des zones calmes et un diagnostic d'équité environnementale à Montréal', The Canadian Geographer / Le Géographe canadien, vol. 63, no. 2, pp. 184–197, 2019, doi: 10.1111/cag.12511.
[13] K. Lam and Y. T. Chung, 'Exposure of urban populations to road traffic noise in Hong Kong', Transportation Research Part D: Transport and Environment, vol. 17, no. 6, pp. 466–472, 2012.
[14] A. Bocquier et al., 'Small-area analysis of social inequalities in residential exposure to road traffic noise in Marseilles, France', European Journal of Public Health, vol. 23, no. 4, p. 540, Aug. 2013, doi: 10.1093/eurpub/cks059.
[15] J. Brainard, A. Jones, I. Bateman, and A. Lovett, 'Exposure to environmental urban noise pollution in Birmingham, UK', Urban Studies, vol. 41, no. 13, pp. 2581–2600, Dec. 2004, doi: 10.1080/0042098042000294574.
[16] A. Fyhri and R. Klæboe, 'Direct, indirect influences of income on road traffic noise annoyance', Journal of Environmental Psychology, vol. 26, no. 1, pp. 27–37, 2006, doi: 10.1016/j.jenvp.2006.04.001.

[17] M. Kohlhuber, A. Mielck, S. K. Weiland, and G. Bolte, 'Social inequality in perceived environmental exposures in relation to housing conditions in Germany', Environmental Research, vol. 101, no. 2, pp. 246–255, 2006, doi: 10.1016/j.envres.2005.09.008.
[18] H. Kruize, P. P. J. Driessen, P. Glasbergen, and K. Van Egmond, 'Environmental equity and the role of public policy: experiences in the Rijnmond region', Environmental Management, vol. 40, no. 4, pp. 578–595, 2007, doi: 10.1007/s00267-005-0378-9.
[19] R. Lagonigro, J. C. Martori, and P. Apparicio, 'Environmental noise inequity in the city of Barcelona', Transportation Research Part D: Transport and Environment, vol. 63, pp. 309–319, 2018, doi: 10.1016/j.trd.2018.06.007.
[20] C. Tonne et al., 'Socioeconomic and ethnic inequalities in exposure to air and noise pollution in London', Environment International, vol. 115, pp. 170–179, 2018, doi: 10.1016/j.envint.2018.03.023.
[21] T. Verbeek, 'The relation between objective and subjective exposure to traffic noise around two suburban highway viaducts in Ghent: lessons for urban environmental policy', Local Environment, vol. 23, no. 4, pp. 448–467, 2018, doi: 10.1080/13549839.2018.1428791.
[22] T. Verbeek, 'Unequal residential exposure to air pollution and noise: a geospatial environmental justice analysis for Ghent, Belgium', SSM - Population Health, vol. 7, 2019, doi: 10.1016/j.ssmph.2018.100340.
[23] T. Audrin, P. Apparicio, A.-M. Séguin, and J. Gelb, 'Bruit aérien et équité environnementale dans les quatre plus grandes métropoles canadiennes', Canadian Geographer, vol. 64, no. 1, pp. 155–168, 2020, doi: 10.1111/cag.12571.
[24] M. Carrier, P. Apparicio, and A.-M. Séguin, 'Road traffic noise geography during the night in Montreal: An environmental equity assessment', Canadian Geographer, vol. 60, no. 3, pp. 394–405, 2016, doi: 10.1111/cag.12281.
[25] M. Carrier, P. Apparicio, and A.-M. Séguin, 'Road traffic noise in Montreal and environmental equity: What is the situation for the most vulnerable population groups?', Journal of Transport Geography, vol. 51, pp. 1–8, 2016, doi: 10.1016/j.jtrangeo.2015.10.020.
[26] J. A. Casey, R. Morello-Frosch, D. J. Mennitt, K. Fristrup, E. L. Ogburn, and P. James, 'Race/Ethnicity, Socioeconomic Status, Residential Segregation, and Spatial Variation in Noise Exposure in the Contiguous United States', Environmental Health Perspectives (Online), vol. 125, no. 7, Jul. 2017, doi: 10.1289/EHP898.
[27] J. P. Cohen, C. C. Coughlin, and J. Crews, 'Traffic noise in Georgia: sound levels and inequality', Journal of Housing Economics, vol. 44, pp. 150–165, 2019, doi: 10.1016/j.jhe.2019.01.005.
[28] T. W. Collins, S. Nadybal, and S. E. Grineski, 'Sonic injustice: Disparate residential exposures to transport noise from road and aviation sources in the continental United States', Journal of Transport Geography, vol. 82, 2020, doi: 10.1016/j.jtrangeo.2019.102604.
[29] Y. Ogneva-Himmelberger and B. Cooperman, 'Spatio-temporal analysis of noise pollution near Boston Logan airport: Who carries the cost?', Urban Studies, vol. 47, no. 1, pp. 169–182, 2010, doi: 10.1177/0042098009346863.
[30] T. H. Nega, L. Chihara, K. Smith, and M. Jayaraman, 'Traffic noise and inequality in the twin cities, Minnesota', Human and Ecological Risk Assessment: An International Journal, vol. 19, no. 3, pp. 601–619, 2013.
[31] C. Park et al., 'Low income as a vulnerable factor to the effect of noise on Insomnia', Psychiatry Investigation, vol. 15, no. 6, pp. 602–612, 2018, doi: 10.30773/pi.2018.01.14.
[32] G. Walker, Environmental justice: concepts, evidence and politics. Routledge, 2012.
[33] N. Fraser, 'Recognition without Ethics?', Theory, Culture and Society, vol. 18, no. 2, pp. 21–42, 2001.
[34] David. Schlosberg, Defining environmental justice : theories, movements, and nature. Oxford ; Oxford University Press, 2007.

[35] B. Schulte-Fortkamp, B. M. Brooks, and W. R. Bray, ‘Soundscape: an approach to rely on human perception and expertise in the post-modern community noise era’, Acoustics Today, vol. 3, no. 1, pp. 7–15, 2007.
[36] G. A. Flamme et al., ‘Typical noise exposure in daily life’, International Journal of Audiology, vol. 51, no. sup1, pp. S3–S11, Feb. 2012, doi: 10.3109/14992027.2011.635316.