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Evaluating Exposure to Road Traffic Air and Noise Pollution: A Comprehensive Review of Assessment Methods

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Keywords:
Air pollution; Combined exposure; Dispersion models; GIS; Modeling techniques; Noise pollution; Traffic data.

Highlights:

- Outline key issues, research gaps, and directions for future investigations into urban traffic pollution.
- For review, assessment of dispersion models, geographical information system tools, and spatial exposure.
- Examine key factors influencing traffic pollution, such as the study locations, sample sizes, traffic data, and building geometry.
- 29% of air pollution studies used NO2; 34% of noise studies used Lden, highlighting their significance in pollution research.

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Abstract: Road traffic contributes to air and noise pollution in urban areas, negatively impacting human health. Understanding exposure to air and noise pollution from road traffic is vital for epidemiological studies on human health. This paper aims to (i) summarize current modeling and assessment methods for road traffic-related air and noise pollution, (ii) emphasize the potential of existing tools and techniques for assessing combined air and noise exposure, and (iii) highlight associated challenges, research gaps, and priorities. The paper examines literature concerning air and noise pollution caused by urban road traffic, including dispersion models, Geographic Information System (GIS) tools, spatial exposure assessment scales, study locations, sample sizes, traffic data types, and building geometry information. Approximately 29% of accredited research parameters for air pollution utilized NO2, underscoring the significance of this element in the research context. Additionally, L_{den} was employed in nearly 34% of publication parameters for noise pollution. Deterministic modeling is the most commonly used technique for assessing short-term and long-term exposure to air and noise pollution. Among the models, more diversity is in air pollution models than in noise pollution models. Correlations between air and noise pollution vary widely and are influenced by numerous factors, such as traffic characteristics, building attributes, and meteorological conditions. Buildings serve as barriers to pollution dispersion, with a more significant reduction effect observed for noise pollution than for air pollution. Meteorology plays a greater role in influencing air pollution levels than noise pollution, although it is also essential for noise pollution assessment. There is considerable potential for developing a standardized tool to assess combined exposure to traffic-related air and noise pollution, facilitating health-related studies. With its geographic capabilities, GIS is well-established and well-suited to address air and noise pollution assessments simultaneously.

تقييم التعرض لتلوث الهواء والضوضاء الناتج عن حركة المرور على الطرق: مراجعة شاملة لأساليب التقييم

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الخلاصة

تساهم حركة المرور على الطرق في تلوث الهواء والضوضاء في المناطق الحضرية، مما يؤثر سلبًا على صحة الإنسان. يعد فهم التعرض لتلوث الهواء والضوضاء الناجم عن حركة المرور على الطرق أمرًا بالغ الأهمية للدراسات الوبائية التي تركز على صحة الإنسان. تهدف هذه الورقة إلى (١) تلخيص طرق النمذجة والتقييم الحالية لتلوث الهواء والضوضاء المرتبط بحركة المرور على الطرق، (٢) التأكيد على إمكانات الأدوات والتقنيات الحالية لتقييم التعرض المشترك للهواء والضوضاء، و (٣) تسليط الضوء على التحديات المرتبطة بذلك، الفجوات البحثية والأولويات. تتناول هذه الورقة الأدبيات المتعلقة بتلوث الهواء والضوضاء الناجم عن حركة المرور على الطرق في المناطق الحضرية، بما في ذلك نماذج التشتت، وأدوات نظام المعلومات الجغرافية(GIS) ، ومقاييس تقييم التعرض المكاني، ومواقع الدراسة، وأحجام العينات، وأنواع بيانات المرور، والمعلومات الهندسية للمباني. ما يقرب من ٢٩٪ من معايير البحوث المعتمدة لتلوث الهواء تستخدم ثاني أكسيد النيتروجين، مما يؤكد أهمية هذا العنصر في سياق البحث. بالإضافة إلى ذلك، تم استخدام L_{den} في ما يقرب من ٣٤٪ من معايير النشر للتلوث الضوضائي. النمذجة الحتمية هي التقنية الأكثر استخدامًا لتقييم التعرض القصير والطويل الأجل لتلوث الهواء والضوضاء. ومن بين النماذج، هناك تنوع أكبر في نماذج تلوث الهواء مقارنة بنماذج التلوث الضوضائي. تختلف الارتباطات بين تلوث الهواء والضوضاء بشكل كبير وتتأثر بعوامل مثل خصائص حركة المرور وسمات البناء وظروف الأرصاد الجوية. تعمل المباني كحواجز أمام انتشار التلوث، مع ملاحظة تأثير خفض أكبر للتلوث الضوضائي مقارنة بتلوث الهواء. تلعب الأرصاد الجوية دورًا أكبر في التأثير على مستويات تلوث الهواء مقارنةً بالتلوث الضوضائي، على الرغم من أنها ضرورية أيضًا لتقييم التلوث الضوضائي. هناك إمكانات كبيرة لتطوير أداة موحدة لتقييم التعرض المشترك لتلوث الهواء والضوضاء المرتبط بحركة المرور، وتسهيل الدراسات المتعلقة بالصحة. تعتبر نظم المعلومات الجغرافية، بفضل قدراتها الجغرافية، راسخة ومناسبة تمامًا لمعالجة تقييمات تلوث الهواء والضوضاء في وقت واحد.

الكلمات الدالة: تلوث الهواء، التعرض المشترك، نماذج التشتت، نظم المعلومات الجغرافية، تقنيات النمذجة. التلوث الضوضائي، بيانات المرور.

1.INTRODUCTION

Air pollution leads to approximately 7 million untimely fatalities annually, establishing it as the foremost global peril to public health in environmental challenges [1,2]. Roughly, 89% of these premature deaths happened in low- and middle-income countries. According to the World Health Organization (WHO), one of the top 10 environmental health concerns is noise pollution in the Southeast Asian and Western Pacific regions. It is estimated that environmental noise causes 48,000 premature deaths each year worldwide. In Asia, the number of premature deaths due to environmental noise is estimated to be even higher, at 120,000 per year [3], and the last two decades highlighted the substantial impact of environmental factors like noise and air pollution on health. These elements are the leading causes of the burden of environmental diseases [4]. Among various shared sources in urban environments, road traffic stands out as the primary catalyst of pollution by air and noise [5]. According to recent United Nations statistics, the current worldwide urban populace constitutes 55%, with an estimated surge to 68% by 2050. Nearly, 90% of this urban expansion is foreseen in Asia and Africa, underscoring the imperative to confront environmental issues linked to urban centers, encompassing traffic emissions and noise pollution [6]. Before 1999, only a few studies considered the aspect of air-noise pollution to examine their correlations [7,8] and their impacts [9]. The outcome many of them found puzzling correlations. Lately, more and more research has emerged showing the growing worry about the combined exposure to pollution and its relationship to urban dwellers' socioeconomic status [10]. Also, it is pointed out that socioeconomic factors may significantly influence the traffic pollution effects and highlighted the assessment of combined exposures recognized as a significant challenge for the upcoming decade [11]. More investigation is required to enhance comprehension of the interconnected and potentially confounding relationships between air/noise pollution when experienced simultaneously in urban areas. Nevertheless, the research community may need access to and awareness of the necessary instruments to facilitate and expedite such investigations [12]. Several tools and techniques are available for analyzing air and noise pollution exposure originating from road traffic. One prominent technology that has reached a high level of development in this field is Geographic Information Systems (GIS). The GIS utilization to map pollution and assess exposure has reached a level of maturity. Open-source and commercially available geospatial tools, collectively called GIS tools, have gained significant traction among researchers worldwide for these applications [13–15]. The maps illustrating noise and air pollution are constructed with a Geographic Information System (GIS) in the nature of the spatial structure of both pollutants [12] is a professional tool for integrated assessment of air and noise pollution in urban areas as it is spatial structure-based. Particularly, the BioShare-EU project has formulated a single database that is free to access, a modern development in this area. "According to the US EPA (2017), this methodology is "the very first of its kind, which marked a meaningful time in improving the effectiveness of assessment approaches by simultaneous integration of two models, particularly, AERMOD and the CNOSSOS-EU [16,17]. Noise model programs like Computer-Aided Noise Abatement (CADNA-A), Integrated Noise Model for Military Installations (IMMI), and SoundPLAN, which can be used simultaneously for air pollution, can be regarded as integrated models for air pollution. Subsequently, other modeling programs and methods are implemented globally to address air and noise pollution issues [18]. This article investigates and elaborates on the modern techniques of road noise and air pollution modeling due to traffic by providing the literature and comparing the results with factors influencing the process. For this purpose, exploration and analysis of pieces of research concerning pollution simultaneity and association with human health were conducted, placing a particular emphasis on their interconnectedness, devising instruments that would be used for the research, and listing down the issues that there would be as well as the gaps that exist and the associated priorities. The gap in this study lies in identifying the main challenges and opportunities for future research. This review paper includes a comprehensive approach to assessing road traffic-related air and noise pollution by integrating information from different sources. The novelty of the review paper lies in its focus on the potential to evaluate joint exposure to these pollutions, its comprehensive examination of current modeling and assessment methods for air and traffic-related noise pollution, and its identification of the most appropriate modeling method.

2.METHODOLOGY

A methodical exploration of existing works was conducted to recognize pertinent research encompassing the modeling and evaluating air and noise pollution from road traffic. The search was confined to papers published between 2013 and 2023, accessible through the Science Direct and PubMed platforms. A tailored search strategy was adopted, given the extensive body of literature about air and noise pollution. Keyword clusters related to "road traffic," "air pollution," "noise," "modeling," "exposure," and "assessment" were employed to enhance search precision. Although the principal thrust was on works concerning road traffic-induced air/noise pollution, the inquiry also revealed that numerous investigations employed Geographical Information Systems techniques. In light of this, the search scope was broadened to ensure including pertinent studies Appendix 1. Consequently, the discussion of GIS concerning pollution modeling of air and noise and impact evaluation was subsequently incorporated [14]. The paper employs a comprehensive approach to examine air and noise pollution factors. For air pollution, the study investigates various parameters, such as Particulate matter (PM2.5, PM10) micrometer diameters, Nitrogen Dioxide (NO2), Nitrogen Oxides (NO_X), Nitric Oxide (NO), Ozone (O3), Sulfur Monoxide (SO), Black Carbon (BC), and Volatile Organic Compounds (VOCs). The paper discusses the relevance and applications of each parameter in understanding air quality. The paper explores different techniques and models for noise pollution, including L_{den}, L_{night}, L_{Aeq}, $L_{Aeq\ 24h}$, L_{Aeq16}, L_{eve}, L_{day}, and L_{dn}. Each parameter is scrutinized for its effectiveness in assessing and quantifying noise pollution levels. The study also evaluates using GIS tools in noise pollution assessment, focusing on popular platforms like ArcGIS, QGIS, and PostgreSQL, along with associated tools like GDAL and PostGIS, Table 1. The technologies in the paper provide overarching datasets related to air and noise pollution parameters. Additionally, the research acknowledges the significance of Geographic Information System (GIS) tools in spatial analysis, offering insights into the role of platforms, such as ArcGIS, QGIS, PostgreSQL, GDAL, and PostGIS in advancing research methodologies in this field [1,5,10,15].

Table 1 Description of Selected GIS Tools Used in Air and Noise Traffic Pollution.

GIS tools	Air pollution parameters	Noise pollution parameters
ArcGIS	NO2	L_{den}
QGIS	NO_X	L_{night}
PostgreSQL,	NO	L_{Aeq}
GDAL	PM10	$L_{Aeq\ 24h}$
Post GIS	PM2.5	L_{Aeq16}
	CO	L_{eve}
	O3	L_{day}
	SO	L_{dn}
	BC	

For papers concentrating on either air or noise pollution, commentaries, editorials, news articles, and bulletins, the initial pool of 410 articles, accounting for duplicates, underwent manual scrutiny primarily guided by the criteria above, resulting in a refined selection of 79 potentially pertinent articles, Fig. 1. These studies are comprehensively enumerated in Appendix 1, accompanied by delineations of air and noise pollution models, pollution metrics and indicators, spatial dimensions of exposure assessment, GIS tools employed, study locales, characteristics of input datasets, and other relevant attributes.

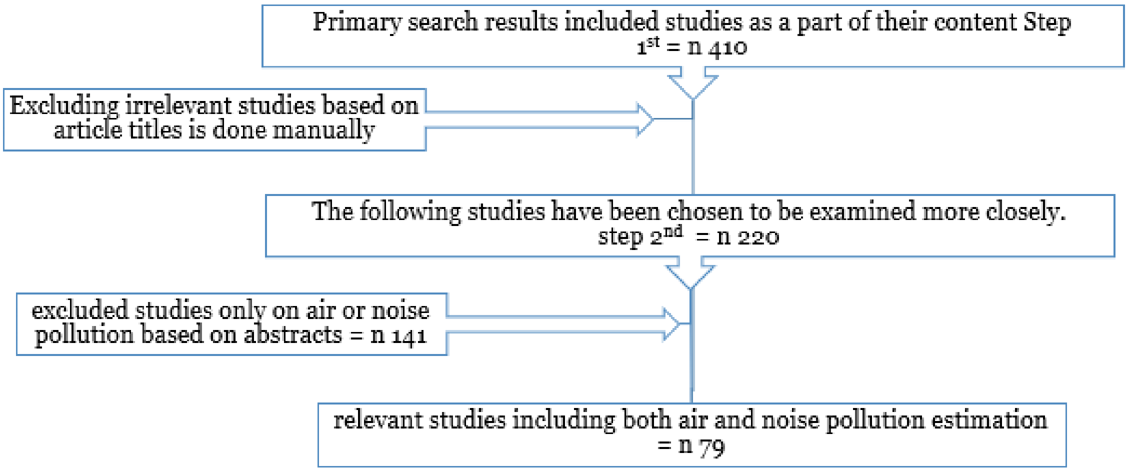

Fig. 1 Process of the Retrieved Articles and Studies the Manual Screening and Refining.

2.1.Techniques Used

This section presents a concise overview of research encompassing various methods for assessing air and noise using air and noise pollution models. To organize the selected studies effectively, they are categorized into two general types of techniques, as outlined by [19]: (1) statistical modeling, which includes land use regression (LUR) models, and (2) measurements/sampling, encompassing both passive/active and mobile/static approaches (hereafter referred to as measurements).

Nonetheless, it is important to note that some studies indirectly employ alternative techniques or methods to assess the impact of air and noise pollution. Stochastic and deterministic modeling approaches incorporate validation information and data assimilation, such as field measurements. Appendix 1 provides a comprehensive list of relevant studies grouped according to their primary techniques.

2.2.Data Measurements

Active or passive sampling is how air pollution assessment methodologies are often categorized [20]. More than 20% of studies [5, 21–24] applied new field initiatives for air/noise pollutant measurements. So, air-noise relationships appear to be high. For instance, [14] generated a linear model based on air and noise measurement with a high validation accuracy of 82%. Typically, calibrated data are regularly used in model construction and evaluation [25,26]. It was noticed that most researchers used static (fixed point) measurements to evaluate air noise [25,27–29]. While others are based on mobile measurements [26,28,30,31]. Low-cost sensor-based UAV measurements improve data's spatial resolution and enable long-term monitoring operations [32].

2.3.Statistical Models

It is well-recognized that noise can have negative impacts on health beyond hearing. The relationship between sound and air quality was examined in several ways. In various metropolitan environments, noise pollution was compared to air pollution [33]. Researchers have conducted regression analyses using pedestrian-level air quality data in earlier research. This methodology was followed, and a regression analysis of the High Line data was conducted [28]. The definite trends of air/noise pollution throughout various years in different megacities would be better understood due to these statistical comparative assessments and subsequent mitigation efforts [34]. Based on Appendix 1, many studies, e.g. [35–39], have used air and noise statistical models for the evaluation of air pollution and to determine the correlation between air pollution and noise pollution.

2.3.1.Noise Models

Ovenden et al. [40] found that the elements influencing traffic-related noise levels for noise pollution analysis, the more recent and open-source CNOSSOS-EU model for industrial applications is appropriate and accurate since it offers a standardized and uniform method for noise mapping and noise computation throughout the European Member States [16]. This integration addressed the four main noise sources: air, train, road, and industrial noise. By integrating geographical data, users can improve their noise evaluations with the help of advanced mathematical algorithms, accurate parameters for input analysis, and detailed information about sources in a smooth Geographic Information System (GIS) [14]. The model was equipped with an intuitive integration interface, frequent updates, and the ability to work under diverse conditions, improving its capability to account for geographic differences and intricate urban environments. Important illustrations of noise exposure measurement models were TRANEX, CadnaA (developed by DataKustik GmbH), and SoundPLAN [41,42]. SoundPLAN tool ensures easy integration with GIS data to develop case- or site-specific noise models by international guidelines and recommendations for noise assessments [22]. It helps analyze sound sources correspondingly and introduces a clear understanding of the noisemaking dynamics through modeling and analysis of various types of sound. Additionally, noise indices, noise contours, and noise reduction strategies can be computed using it [23]. For noise assessments, they must adhere to UK and European regulations and require a high degree of precision and information. SoundPLAN is appropriate for noise assessments where compatibility, functionality, dependability, and adherence to Australian and European standards are required [36]. Numerous calculating techniques, including CoRTN, NMT, Nord 2000, ISO 9613, and FHWA, are supported. In addition, it is capable of managing, optimizing, mapping, and monitoring noise [21,39]. According to the study, most academics have relied on regression modeling, and they rarely developed a model to anticipate traffic noise using evolutionary computing techniques like genetic algorithms, fuzzy systems, or neural networks [43]. It is interesting to note that open-source noise mapping and prediction models are becoming increasingly popular due to their simplicity and effectiveness. A few recently released studies, such as [5,21,24,44], clarify this.

2.3.2.Air Pollution Models

The AirGIS/OSPM and the KCL-Urban are the most commonly mentioned deterministic air pollution exposure assessment models [45]. Gaussian is used dispersion equation for the direct contribution of the traffic emissions to the street concentration and a box model for the recirculated part of the pollutants in the street canyon. The Danish Cancer Society research team was in charge of several papers considered in Appendix 1 and used AirGIS/OSPM [22,46,47]. The impacts on health were the main concern. The Box model Eq. (1) for air pollution using OSPM is:

$$C_r = \frac{Q}{V}\frac{1}{k} \qquad (1)$$

where Cr is the recirculated contribution, Q is the emission rate, V is the volume of the recirculation zone, and k is the ventilation rate EURAD-CTM [48] is one of the less frequently employed models Appendix 1. One of the EURAD model's submodules that estimates air pollutants' dynamic behavior is EURAD-CTM, using meteorological input and emissions inventories. An integrated dispersion modeling system called AERMOD is publicly available to the scientific community [49,50]. Although it was only occasionally used in the research, it is examined in Appendix 1. AERMOD is a widely used model in studies dealing with air pollution [51,52]. Where pollutant dispersion is calculated using AERMOD in urban and rural settings, on level and raised terrain, and with several emission sources (point, area, and volume) dependent on the formula: The Gaussian dispersion equation Eq. (2) used in AERMOD is:

$$C(x) = \frac{Q}{2\pi\sigma_y\sigma_z} exp\left(-\frac{y^2}{2\sigma_y^2}\right) exp\left(-\frac{z^2}{2\sigma_z^2}\right) \qquad (2)$$

where $C(x)$ is pollutant concentration at the receptor location x, Q is pollutant emission rate (source strength), σ_y and σ_z are horizontal and vertical dispersion coefficients, y is crosswind distance from the plume centerline to a receptor, z is the vertical distance from ground level to the receptor.

Moreover, various research and reviews list and compare the available atmospheric dispersion models [53–56].

2.4.Modeling Parameters

Investigating the impact or relationship of definite parameters on air pollution can offer information for more effective monitoring [14]. When predicting factors for dynamic link-based emissions of key air pollutants, parameters like road characteristics, population density, and land use data are considered [57]. Air quality deteriorates as a result of noise and various air pollutants. Weather can significantly influence recurring factors that result in seasonal noise fluctuations, in addition to transportation as the primary source of noise pollution [58,59]. Prior studies have helped advancements in traffic noise prediction analytics that use robust analytical and computational models and traffic, road parameters, and environmental parameters [60]. For setting up new modeling domains, arithmetic, and binary GIS datasets, i.e., a collection of good quality and insinuation integration, the GIS dataset measures good-quality laser data from several data sources. These online GIS datasets were acquired because they are largely updated and derived from online sources [61,62].

2.4.1.Air Pollution Parameters

The work of Pinto et al. [63]; addressed the need to determine the emissions caused by vehicles and the limitations of various air quality models, such as boundary conditions, wind behavior representations, chemical mechanisms, and reactions; was conducted as a systematic review of the key traffic variables used in emissions and air quality modeling. For studies based on regression analysis, parameters are predictable at any point in an array of one or more independent factors selected in place for a known position and a site-specific parameter-dependent [35,38,64]. The parameter surfaces that the models anticipate offer fresh lines of inquiry into the general problems of feature changes and the behavior validity of global information, as well as into the particular processes of the environment under study [59,64,65]. The correlation between some parameters, such as hematologic metrics and a potential pro-inflammatory condition with air pollution, was underlined by [66]. Existing these relationships and PM10 highlights the need to review environmental health strategies. Air pollution parameters vary based on location and kind of area. Ref. [67] emphasized the effects of industrial regions and suggested utilizing alternative techniques and mitigation measures for monitoring, controlling, and limiting exposure to particles and pollutants from industries. [1,52,68,69] in Appendix 1. Air pollutant parameters were categorized according to how they were used in modeling. The percentages were displayed: The highest percentage of paper publications was used for NO2, at 29%, and PM10, at 26%. For modeling purposes, 22 percent of PM2.5 was also utilized. About 12% of works of paper research employed NO_X, as a modeling parameter; less than 5% of works used other parameters, such as CO, O3, SO, NO, and BC, as shown in Fig. 2.

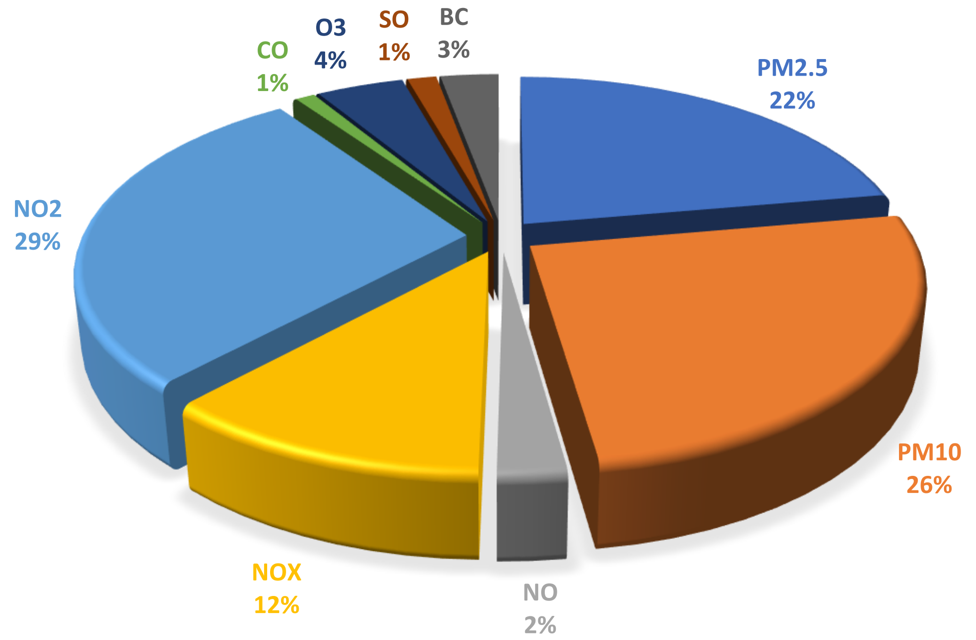

Fig. 2 Indicators for Assessing Road Traffic Air Pollution Exposure. This Review Demonstrates the Prevalence of Exposure Indicators in the Percentage of the Studies Included.

2.4.2. Traffic Noise Parameters

Many important variables that affect traffic noise still need to be investigated, including the pavement type, vegetation surrounding roads, road slope, and surface roughness [43, 70]. The relationship between noise exposure and its effect was documented based on a wealth of research. To develop models and assess the correlation coefficient between the noise-attitude parameters, the annoyance curve was plotted against a specific noise parameter, such as L_{den}, L_{night}, L_{Aeq24}, L_{eq}, and L_{dn} [71]. Before adopting or recalibrating existing traffic noise models for local demand, it is necessary to understand their variations and underlying assumptions. For this purpose, 11 traffic noise parameters have been used by various agencies in different parts of the world based on outdoor and indoor measurements. Considering the expense and effort put forth in creating these models [58,60] used noise parameters such as maximum and minimum noise with weather factors to estimate air pollution in terms of PM2.5, significant corrections were determined by the study between air pollution and noise parameters. Also, traffic aspects with indicators of motorcycle volume and traffic density, road physical aspects with the super-elevation indicator, and environmental aspects of the road with the air temperature indicator are the variables that can be used as parameters or indicators of heterogeneous traffic noise triggers in urban areas [72]. In Appendix 1, noise pollution parameters were classified according to their uses in modeling, and the percentages were presented as follows: 34% of total publications used L_{den} as a maximum report. Other parameters were reported, such as L_{Aeq} was reported at 13%, while $L_{Aeq\ 24h}$ was reported at 14%, in the other hand, L_{Aeq16} was reported at 5%. L_{day} used by studies was 7%, while L_{night} reached 17%. L_{eve} reported 6%, and L_{dn} was the lowest parameter reported by literature with 4% [25,39,51,52,73,74], as shown in Fig. 3.

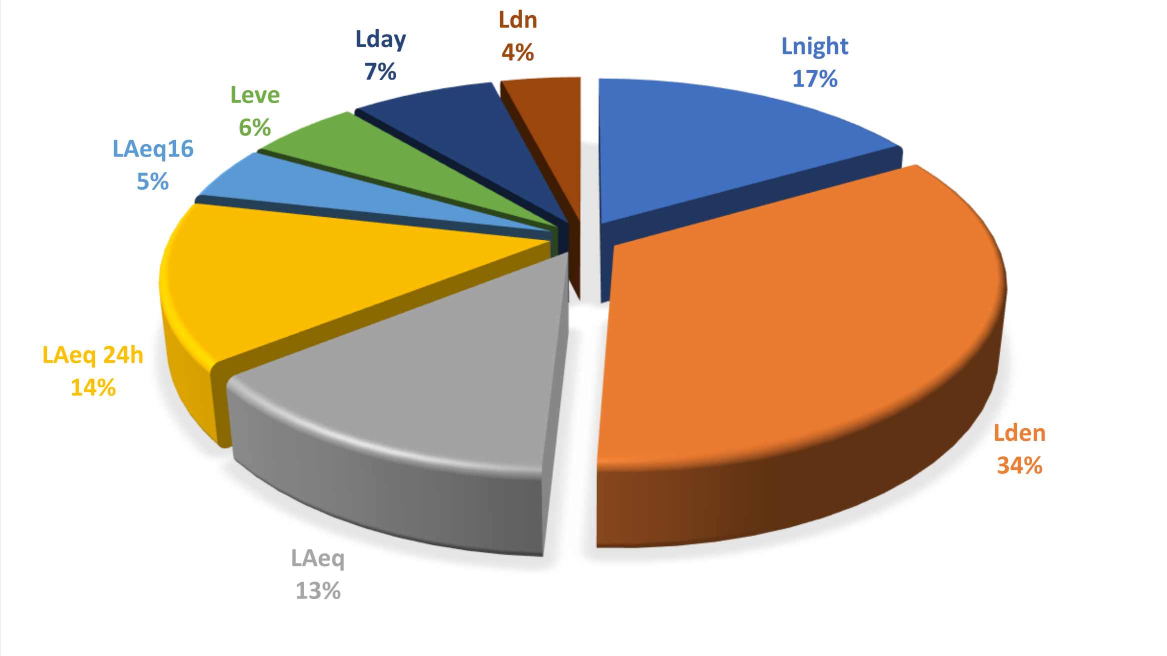

Fig. 3 Indicators for Assessing Road Traffic Noise Exposure. This Review Demonstrates the Prevalence of Exposure Indicators in the Percentage of the Studies Included.

2.5.Effects of Meteorology on Air and Noise Pollution

Understanding, observing, and reducing noise and air pollution depend on meteorology [14,23]. The dispersion and concentration of contaminants in the air are directly impacted by the dynamic nature of the atmosphere, which meteorology investigates. Exploring the complex interaction between meteorology, air pollution, and noise pollution, which affects the propagation of noise through the environment, and drawing insights from relevant scientific literature [14].

2.5.1.Air Pollution and Meteorology

The intricate relationship between meteorology and air pollution, highlighted by various studies [58,65,75–77], underscores the crucial role of meteorological variables like temperature, wind speed, and atmospheric stability in generating and dispersing ozone, directly impacting the concentration and dispersion of air pollutants with implications for the environment and human health [67,77]. Wind, a significant weather factor, plays a key role in the spread of air pollution, as strong and continuous winds locally decrease pollutant concentrations, while low wind speeds, particularly in urban areas, can lead to stagnant air and the buildup of pollution [78,79]. When a layer of warm air ensnares a layer of cooler air with pollutants below it, temperature inversions potentially exacerbate pollution-related problems. Inversion-friendly conditions and their effects are easier to spot because of meteorology [80]. The amount of humidity impacts how aerosols and other airborne particles form [76,81]. Also, there are stable and unstable atmospheric conditions, according to meteorology. While unstable conditions enhance vertical mixing, which can spread pollutants, stable conditions frequently linked to high-pressure systems can store pollutants near the ground [78].

2.5.2.Noise Pollution and Meteorology

Because sound waves propagate, weather factors significantly impact noise [20]. Depending on the temperature differences in the atmosphere, sound waves move at various speeds. These speed differences may result in sound refraction, which bends sound waves and allows them to travel farther [82]. Noise transmission can be impacted by wind. Ground cover and topography also affect noise levels [83]. The atmosphere is capable of absorbing sound waves, especially at higher frequencies. This absorption is influenced by meteorological factors, including humidity and aerosols [84]. To effectively manage the environment, one needs a comprehensive grasp of the intricate interplay between pollution and weather, enabling businesses and governments to predict and regulate pollution events using meteorological information, sophisticated modeling, and monitoring systems like air quality predictions [85]. Furthermore, understanding air/noise pollution distribution and impacts heavily relies on meteorology, empowering stakeholders to make informed pollution reduction and management decisions, ultimately improving air and noise quality through utilizing precise meteorological data and models.

2.6.Role of ArcGIS in Air-Noise Pollution Evaluation

The Operational Street Pollution Model (OSPM®), based on Geographic Information

Systems (GIS), and AirGIS, a GIS-based system for air pollution and human exposure modeling, are the common methods used to evaluate air pollution at the local or street level across the globe. Table 2 summarizes various GIS-based approaches developed between 2013 and 2023 for estimating exposures to combined air and noise pollution. Within this list of 31 research works, six employed PostGIS and PostgreSQL, while only one study used GDAL, with ArcGIS being the most commonly applied GIS tool. QGIS was also used in three studies, as illustrated in Appendix 1.

Table 2 GIS-Based Approaches Developed for Assessing Air and Noise Pollution Exposure.

No	GIS Tools	Number of Studies
1	Arc GIS (Arc Info /Arc View)	31
2	PostGIS	6
3	PostgreSQL	6
4	QGIS	3
5	GDAL	1

A useful way to create maps showing air pollution levels is to employ land use regression (LUR) models. They also act as a predictive component that may be accessed as a separate raster disk. It is critical to recognize that a script dependent on pollution levels may provide unfavorable results. Describing the LUR model computing process includes a Python demonstration of the procedure. This novel method analyzes the driving tendencies of the leading PM1 species and the total PM1 concentrations using data-driven statistics [86]. Air quality models (AQMs) offer the opportunity to identify the sources of air pollutants and help analyze different types of air pollution. Based on studies on air quality, it can be concluded that land-use regression (LUR), machine learning, and hybrid methods are the most widely used techniques for estimating air pollution. Additionally, it produces promising results when traffic factors are combined with LUR approaches. Nevertheless, when kriging or inverse distance weighting techniques are used, the monitoring stations' air pollution data readings are sufficient to produce good results. Given the limitations, such as the availability of datasets and technical/computing resources, A brief guide for anyone who wants to develop an AQM is provided in [87]. The equation of the LUR model can be stated as:

$$\boldsymbol{C = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_n X_n + \epsilon} \quad \textbf{(3)}$$

where C is the pollutant concentration, β_0 is the intercept, $\beta_{1,2,\ldots}$ is the number of regression coefficients, $X_{1,2,\ldots}$is the set of factors related to land use and traffic, and ϵ is the error term [59,67,76,87]. The Gaussian plume, on the other hand, is a uniform model that regards an air disturbance as regular and stationary. Based on [88], creating a plugin involves several key steps, such as (i) using Plugin Builder to create the plugin framework, (ii) changing the plugin, (iii) increasing the graphical user interface (GUI) ability to accept plugins; and (iv) creating a custom map tool. Python is used in the Gaussian Plume Equation programming. The primary variables employed in the analysis of the pollutant concentration are the wind speed (Raster Layer), release location (Vector Layer), release height, stability class (in the instance B and C), and the distribution of parameters in the crosswind (y) and vertical (z) directions (y and z). The expression for the Gaussian from a point source is:

$$\boldsymbol{C(x,y,z) = \frac{Q}{2\pi\sigma_y\sigma_z u} exp(\frac{-y^2}{2\sigma_y^2})[exp(\frac{-(z-h)^2}{2\sigma_z^2}) + exp(\frac{-(z+h)^2}{2\sigma_z^2})]} \quad \textbf{(4)}$$

where the downwind, crosswind, and vertical coordinates are *x, y,* and *z,* respectively, the release height from the ground is h, the source intensity is Q, the wind speed is u, and the standard deviations of the distribution concentration in σ_y *and* σ_z are y and z, respectively, in meters. All necessary measurements and parameters are set up in a way proportional to the Python equation's structure. To incorporate the predictor variables used in the final Land use regression LUR model standard, Python was used, which was visualized in ArcMap GIS. In this work, Python has been used to code the Gaussian plume equation in GIS.

3.RESULTS

In this paper, a comprehensive examining the intricate relationships of air/noise pollution was delved into with contemporary modeling context and exposure assessment techniques. The outcomes of the comprehensive literature review and accompanying discussions were presented. Within the studies (as outlined in Appendix 1), some researchers explored the connections between air and noise pollution, including [15,23,37,89,90]. Meanwhile, others focused on assessing the air/noise pollution health outcomes impacts, featuring work by Sørensen et al. [47]. Significantly, the identified studies typical of (totaling 47) employed Geographical Information Systems methods to gauge air/noise pollution exposure, with contributors such as [1, 9, 95, 44, 46, 47, 51, 91–94]. Most of the investigations concerning pollution of air and noise in European cities are predominantly conducted in London in the United Kingdom [10, 36, 96], Copenhagen and Aarhus in Denmark [22, 46, 47], Madrid in Spain [97], Stockholm in Sweden [98], and Leipzig in Germany [73]. It was also evident that relatively fewer studies were conducted in other parts of the world, such as South America, Africa, and Oceania. There is a notable gap in research in these regions, which calls for further investigation. Deterministic modeling is the primary method for assessing air and noise pollution exposure from road traffic, offering versatility for short-term and long-term assessments. Stochastic modeling, like Land Use Regression (LUR), is better for long-term exposure. However, there is no standardized tool for modeling dual exposure simultaneously. Studies show variations in air and noise pollution correlations due to various exposure models and techniques. Traffic attributes like volume, speed, vehicle type, and meteorological conditions significantly impact air pollution levels.

4.CONCLUSIONS

By comparing the selected literature in the present study, the relation factors of association between air pollution and noise were deduced using modern modeling and exposure assessment methods. The correlations and the influencing factors besides meteorology impact, were discussed. Based on the results, the study concludes that the wide-ranging variability can be attributed to several factors falling within one or more categories, including (a) exposure techniques, (b) the heterogeneity of pollution indicators with varying spatial patterns, (c) the spatial scale of exposure assessment and sample size, (d) attributes related to traffic, (e) characteristics of buildings, (f) meteorological conditions, (g) the urban landscape, and (h) background contributions. The research highlights the challenge of evaluating motor vehicle-based pollution of air and noise using extensive data. Deterministic modeling is popular for short-term evaluations, while stochastic models like Land Use Regression (LUR) perform better for extended periods. The air and noise pollution relationship is impacted by several variables, such as weather, and traffic aspects. Perfect correlation is unachievable; however, GIS may facilitate data integration by gathering and analyzing input data, performing computations, and understandably displaying the findings, which can expedite research and policy formulation. For future works, the GIS methodologies mentioned in this paper are pivotal in amalgamating harmonized data and validated models to achieve address-level or personalized exposure estimates. This paradigm shift promises a deeper understanding of the health implications of air and noise pollution, aiming to mitigate confounding factors that often muddle health studies.

6.APPENDICES

Appendix 1 Summary and Description of Selected Studies of Techniques and Tools Used in Air and Noise Traffic Pollution.

No	Study (Ref.)	Air Pollution Parameters	Air Pollution Models and Technique	Traffic Noise Parameters	Traffic Noise Models And Technique	Gis Tools	Country	Sample Size	Geometry of Building
1	[1]	PM10, PM2.5, NO2, and NOx	DEHM/UBM/AirGIS model	L_{den}, $L_{Aeq,24h}$	Nord2000 model	ArcGIS	Denmark	24,538	NO
2	[5]	PM10 and PM2.5, NO2	QGIS	L_{den}, $L_{Aeq,24h}$	CRTN method / CNOSSOS-EU	QGIS	Scotland	/	Yes
3	[10]	O3, PM2.5, PM10, NO2, NOx	KCL-Urban	L_{Aeq16h}	TRANEX	PostGIS, PostgreSQL,	UK	5,482	Yes
4	[11]	NO2	ADMS-Urban	$L_{Aeq,24h}$	MITHRA-SIG	ArcGIS	France	10,825	Yes
5	[15]	NOx, NO2, PM10, and PM2.5.	OSPM / AirGIS	L_{day}, L_{eve}, L_{night}, L_{den}, and $L_{Aeq,24h}$	CNOSSOS-EU	ArcGIS	Denmark	12,500	Yes
6	[19]	PM2.5, UFP, EC, NO2	DEHM/UBM/AirGIS model	L_{denMax}, L_{denMin}	Nordic Method	/	Denmark	1.9 million	NO
7	[21]	PM2:5 and NO2	DEHM/UBM/AirGIS model	L_{den}, $L_{Aeq,24h}$	Nord2000 model	ArcGIS	Denmark	23,528	NO
8	[22]	PM10 and NOx	OSPM /AirGIS	L_{eve}, L_{night}, L_{den}, L_{Aeq}, L_{day}	Sound PLAN	ArcGIS	Denmark	57,053	Yes
9	[23]	NO, NO2, NOx, and O3	RLINE modeling	$L_{eq,5min}$, L_{den}	Sound PLAN	other	Turkey	/	Yes
10	[24]	PM2.5, NO2	DEHM/UBM/AirGIS model	L_{den}	Nord2000 model	ArcGIS	Denmark	28 727	NO
11	[25]	PM, SO2, NOx, and NO2	Static, Passive, field campaign	$L_{eq125Hz}$, L_{eq2kHz}, L_{AeqL50}, L_{lineq}, $L_{lineqL50}$	Field campaign, Static	Other	Netherlands	/	NO

12	[26]	UFPand BC	Mobile, field campaign, Active	$L_{A01,1h}$, $L_{A05,1h}$, $L_{A50,1h}$, $L_{A95,1h}$, $L_{Aea,1h}$	Field campaign, Mobile	Other	Belgium	/	NO
13	[27]	NO2 and PM10	Static, Passive, field campaign	L_{den}	TRANEX	PostGIS, PostgreSQL,	New Zealand	26,610	Yes
14	[28]	PM2.5	Mobile, field campaign, Active	L_{Aeq}, L_{A10}, L_{A90}	Field campaign, Mobile	/	USA	/	NO
15	[29]	NO2, BC, and EC	Static, Passive, field campaign	$L_{Aeq,10min}$	Field campaign, Static	/	Spain	2,897	NO
16	[30]	PM2.5, BC, and CO	Mobile, field campaign, Active	L_{Aeq}	Field campaign, Mobile	/	China	40	No
17	[31]	PAH, O3, and NO2	Static, Passive, field campaign	L_{Aeq}	Field campaign, Mobile	Other	Sweden	/	
18	[35]	NO2	Spatial regression	L_{aeq}	Spatial regression	GDAL	Canada	/	Yes
19	[36]	PM2.5, PM10, NOx, NO2, and O3	KCL-Urban, Road Source Model	L_{Aeq16h}	TRANEX	PostGIS, PostgreSQL,	UK	18,138	Yes
20	[37]	PM10, PM2.5, and NO2	Passive, static, field campaign	L_{den}, $L_{Aeq,24h}$ L_{night}	STAMINA model	ArcGIS	Netherlands	354,827	Yes
21	[37]	(PM 10, PM 2.5), NO2	specific dispersion model	L_{den} , L_{night}	specific dispersion model or exposure technique	/	Netherlands	354,827	NO
22	[38]	NO2 and PM2.5 data	Models (GAMs)	L_{dn}	Linear exposure-response function(ERF)	other	Spain	3,511	/
23	[39]	PM2.5, UFP, EC, and NO2	DEHM/UBM/AirGIS model	L_{denMax}, L_{denMin} L_{den}	Nordic Method	other	Denmark	1,971,246	NO
24	[44]	PM10, PM2.5, and NO2	/	L_{den}	STAMINA model	ArcGIS	Netherlands	3,059	Yes
25	[46]	NO2, NOx	OSPM / AirGIS	L_{night}, L_{den} L_{day}, L_{eve},	Sound PLAN	ArcGIS	Denmark	57,053	Yes
26	[47]	PM2.5, NO2	OSPM / AirGIS	L_{den}	Sound PLAN	ArcGIS	Denmark	39,863	Yes
27	[48]	PM2.5, PM10	EURAD-CTM	L_{night}, L_{den}	END method	ArcView	Germany	4,861	Yes
28	[51]	Nox	AERMOD	L_{Aeq} , L_{day}, L_{night} , L_{den}.	Sound PLAN	ArcGIS	Turkey	/	Yes
29	[52]	Nox	AERMOD	$L_{evening\ hours}$	TRN	ArcGIS	Israel	285	NO
30	[68]	PM2.5, PM10, NO2, and NOx	/	L_{den}	Other	ArcGIS	Spain	6,438	Yes
31	[69]	PM10, PM2.5, and NO2	LUR	Lden,Lnight	/	ArcGIS	Netherlands	1,027	NO
32	[73]	PM10	UFIPOLNET	L_{night}, L_{den} L_{day}, L_{eve},	IMMI	ArcGIS	Germany	/	Yes
33	[74]	Nox	LUR	$L_{Aeq,24h}$	computer-generated model (other)	/	Sweden	1,721	NO
34	[89]	NO2 and PM10	Static, Passive, field campaign	L_{day}, L_{night}	EASY MAP model	ArcGIS	France	7,290	Yes
35	[90]	NO2 and Nox	CALINE4	L_{dn}	Traffic Noise Model (TNM)	other	USA	1,345	NO
36	[91]	NO2	EMPARA Luvotool, KCL-Urban	L_{night} $L_{Aeq,24h}$	Other	ArcGIS	Germany, UK, Italy, Greece, Sweden, Netherlands	4,861	Yes
37	[92]	NO2	AERMOD	L_{den}	Sound PLAN	ArcGIS	Sweden	13,512	Yes
38	[94]	PM10, NOx, benzene, and SO2	AUSTAL2000 model CadnaA	L_{Aeq}	CadnaA	ArcGIS, ESRI's	Portugal	56,800	Yes

39	[95]	NO2, PM10, and PM2.5	MCDM-GIS methods	L_{night}	MCDM-GIS methods	ArcGIS	UK	/	Yes
40	[97]	PM2.5, PM10, NO2, and O3	Passive, static, measured data	L_{night}, L_{den}	Static, measured data	/	Spain	3,288	NO
41	[99]	NO2	PSRH	L_{den}	/	other	Bulgaria	917	Yes
42	[100]	NO2, PM2.5, and O3	GEOS-Chem/ LUR	$L_{Aeq,24h}$	Sound PLAN	other	USA	1,612	NO
43	[101]	NO2, PM10, and PM2.5	QGIS	L_{day}, L_{eve}, L_{night}	CRTN method / CNOSSOS-EU	QGIS	Scotland	776,579	NO
44	[102]	NO2 and PM2.5.	/	L_{den}	/	other	Spain	404	NO
45	[103]	PM10, NO, NO2, NOX, PM fractions, and UFP,	models (GAMs)	L_{aeq}	models (GAMs)	/	Netherlands	/	NO
46	[104]	PM2.5, PM10, NO2, and NOx	DEHM/UBM/AirGIS model / OSPM	L_{den}, $L_{Aeq,24h}$	Nord2000 model	Esri's, ArcMap	Denmark	23,093	NO
47	[105]	PM2.5 and NO2	DALY (13) HSD, automobiles	L_{Aeq}	/	/	Japan	415	NO
48	[106]	PM2.5 and NO2	LUR	L_{den}, $L_{Aeq,24h}$	STAMINA model	/	Netherlands	10.5 million	NO
49	[107]	PM10, PM2.5, and NO2	LUR	L_{den}, $L_{Aeq,24h}$	STAMINA model	ArcGIS	Netherlands	339,633	NO
50	[108]	PM10, PM2.5, and NO2	DEHM/UBM/AirGIS model / OSPM	L_{dn}	Nord2000 model	ArcGIS	Denmark	24,541	NO
51	[109]	NOx	/	L_{den}, $L_{Aeq,24h}$	/	ArcGIS	Sweden	6,304	/
52	[110]	PM10, PM2.5, and NO2	LUR	L_{den} , L_{night}	STAMINA model	ArcGIS	Netherlands	2,302	/
53	[111]	PM2.5 and NO2	SGH models.	L_{den}	STAMINA model	other	Netherlands	354,827	NO
54	[112]	PM10, PM2.5, and NO2	LUR	L_{den} , L_{night}	STAMINA model	ArcGIS	Netherlands	3,680	NO
55	[113]	PM1, PM2.5, and PM10	/	$L_{Aeq,24h}$	CadnaA	/	Slovakia	/	NO
56	[114]	PM10, PM2.5, and NO2	LUR	L_{den}	CNOSSOS-EU	GIS data	UK	355,732	NO
57	[115]	UFP, BC, Nox, and PM	LUR	L_{Aeq}	LUR	ArcMap	Canada	270	Yes
58	[116]	Carbon attributable to traffic (ECAT), and PM2.5	LUR	$L_{Aeq,24h}$	DOT model	ArcGIS	USA	370	NO
59	[117]	PM2.5, PM10, PMcoarse, PM2.5 absorbance, NO2, and Nox	ESCAPE	$L_{Aeq,24h}$	Other	other	Germany	4,086	Yes
60	[118]	NO2	AirGIS	L_{den}, L_{night}	Sound PLAN	other	Denmark	84,218	Yes
61	[119]	NO2	AirGIS	L_{den}	Nordic Method/ Sound PLAN	other	Denmark	72,745	Yes
62	[120]	(PM2.5abs) PM2.5 NO2	LUR / ESCAPE	L_{den}, $L_{Aeq,24h}$	CadnaA	open-street map data, Google earth	Germany	5,603	Yes
63	[121]	NO2	AirGIS	L_{dn}	Sound PLAN	other	Denmark	50,744	Yes
64	[122]	Nox, NO2, PM10, PM2.5, and O3	LBW model	$L_{Aeq,16hr}$, L_{night}	TRANEX	other	UK	540,365	NO
65	[123]	PM10 and NO	LUR	L_{den}, L_{night}	CNOSSOS-EU	other	Norway and Netherlands	144,082	NO
66	[124]	BaP and PM2.5	SELMAGIS	L_{den}	LimA v.5	ArcGIS	Bulgaria	513	Yes
67	[125]	PM2.5, PM10, O3, NOx ,NO2, and NO	KCL-Urban, ADMS	L_{Aeq16h}, L_{night} $L_{Aeq,24h}$, L_{den}	TRANEX	PostGIS, PostgreSQL,	UK	9 million	Yes
68	[126]	PM2.5, PM10, NO2, and NOx,	LUR, EURAD-CTM	L_{night}, L_{den}	Other	Other	Germany	4,814	Yes

69	[127]	Nox and PM2.5	KCL-Urban	L_{Aeq16h}, L_{night}	TRANEX	PostGIS, PostgreSQL,	UK	8.61 million	Yes
70	[128]	NO2, PM2.5, and PM10	LUR	L_{den}	EMPARA	Other	Netherlands	3,963	Yes
71	[129]	NO2 and PM10	/	L_{night}, L_{den}, L_{day}, L_{eve}, L_{Aeq16h}	CNOSSOS-EU	PostGIS, PostgreSQL,	UK, Italy, Netherlands	742,950	Yes
72	[130]	Nox	GDM	L_{Aeq}	Nordic Method	QGIS	Sweden	/	Yes
73	[131]	PM2.5	/	L_{dn}	CadnaA	Other	Germany	4,261	Yes
74	[132]	NO2, NO, BC, PM2.5, CO, SO2, and O3	/	L_{night}, L_{den} L_{day}, L_{eve},	CadnaA	/	Canada	678,361	Yes
75	[133]	NO2	/	L_{den}	/	ArcGIS	Canada	68,326	Yes
76	[134]	PM2.5, NO2, NO, EC, and BC	Static, Passive, field campaign	$L_{Aeq,1s}$	Field campaign, Static	Other	USA	/	NO
77	[135]	UFP and PM2.5	Static, Passive, field campaign	L_{Aeq}	Field campaign, Static	Other	USA	/	Yes
78	[136]	EC, NO2, and PM10	Other	L_{den}	SKM2, Urbis	Other	Netherlands	18,213	Yes
79	[137]	PM2.5 and NO2	USBM/AirGIS	L_{den}	Nord2000 model	ArcGIS	Denmark	22,438	Yes

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