






Review

Global Systematic Mapping of Road Dust Research from 1906 to 2020: Research Gaps and Future Direction

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Abstract: Roadside dust resulting from industrialization of society has an adverse effect on the environment and human health. However, despite the global research progress in this field, to date, no bibliometric report on the subject has been documented. Hence, bibliometric mapping is important to assess the quality and quantity of the global research activities on road dust. Data were retrieved from the Web of Science Core Collection and Scopus, while RStudio software was used for data analysis. A total of 1186 publications were retrieved from these databases, and progressive growth in the subject over the last 10 years was observed, considering the positive correlation ($y = 0.0024 \times 3 - 0.1454 \times 2 + 2.6061 \times -8.5371$; $R^2 = 0.961$) obtained for these indices. China had the highest publications, and environmental science-related journals dominated publications on road dust. The findings suggest that other regions of the world, such as the Middle East and Africa, need to channel their research efforts toward this field, considering the shortage of publications on the subject from these regions. Therefore, this study shows that assessing research activity on road dust is important for planning impactful research directions and setting protective and adaptive policies related to the field.

Keywords: road dust; heavy metals; bibliometric; industrial development; traffic system



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1. Introduction

Road transportation is important for sustained and inclusive growth of the economy and plays a key role in increasing social divergence in all nations [1]. When compared to other transport means, road projects improve the economic and societal well-being of people [2]. A good road network can decrease travel time, reduce the costs of transport, and increase income and standard of living; thus, the merits of road transport are indisputable [2]. Regardless of the merits, road transportation activities may constitute adverse effects on the degradation of environmental quality and human health [3]. Anthropogenic activities disrupt the intricate balance among the foregoing constituents of the life support system and have negative consequences on public health [4–6].

Roadside dust, also known as road dust or street dust, is a major source of pollution to the environment, as not only is it just another type of pollution in urban areas, but it is an ideal medium for transferring other contaminants into the environment [7]. Roadside dust is composed of settled materials from construction works [8], soil [9], emissions and soot from vehicles and industries [10,11], and airborne particulates [7,12]. Due to its composition and characteristics, it has adverse effects on humans, plants, and animals. Consequently, it has been considered an excellent environmental pollution indicator of the urban environment [7,13,14]. The possibility of re-suspension (by repeatedly rising,

subsiding, and rising again) and the presence of contaminants, such as heavy metals, at low concentrations within the immediate vicinity of humans, plants, and animals makes road dust very hazardous, as these living organisms are directly or indirectly exposed to it, mostly through inhalation [14]. The presence and levels of heavy metals and other contaminants in roadside dust have been linked to emissions from motor vehicles, and this has been observed to vary among urban regions with different human activities and land uses [15]. The distribution of these contaminants in road dust is associated with land use patterns and the population size of the city in which it occurs [13,16]. Due to the effect of vehicular emissions and urban traffic, road dust contains soil particles <100 µm with more negative health effects and environmental hazards than those of soil particles with sizes <100 µm, and it is capable of adhering to human skin [17–20].

Contamination of road dust or street dust has greatly increased in urban environments due to industrialization and urbanization within the last three decades [21,22], thereby attracting huge, global interest, hence the extensive studies on the subject [7,15,23,24]. Although the research on road dust is gaining attention from different perspectives, such as source identification, concentration profiles, spatial distribution, health risk assessment, and enrichment levels at national and sub-national levels [25–31], there remains a lack of a comprehensive survey of road dust research across these perspective at the global scale.

To understand the interdisciplinary nature of road dust research, publication output related to road dust (or dust) highlights numerous points of difference in ideas and inspires simple conceptualization of probable challenges. Only quantitative data analysis of road dust can define and assess the degrees of publication output on road dust and allow for the establishment of specific goals regarding how to encourage the integration of different disciplines. The quantitative method of data analysis is also helpful in providing a model or baseline for future studies [32]. The use of a bibliometric study is an appropriate method to identify the growth pattern and volume of publications on road dust. Similarly, bibliometric analysis is a suitable approach to identify active researchers, important research themes, and research institutions and countries for future planning, as well as collaboration networks among them on a particular subject or field [33–36].

Thus, researchers need a range of theoretical and practical tools to measure experimental data. Utilizing quantitative analysis, correlation networks, and statistics, the bibliographic and content information of the articles in each field can be analyzed [37]. This statistical method has been employed to quantify research publications on different fields of science, including environmental and public health subjects, such as air pollution and public health [38], sources of atmospheric pollution [39], microplastics in the environment [40], acid rain [41], tuberculosis [42], Alzheimer's disease, [43], HIV/AIDS [44], drinking water research [45], allergy [46], diabetes mellitus and T cells [47], malaria [48], foodborne disease [49], spinal cord injury [50], microbial chlorine resistance in drinking water/water treatment [51], microorganisms' implications in neurodegenerative diseases [52], *Plesiomonas*-related research [53], organochlorine pesticides [54], biofloculants [55], diabetes [56], and renewable energy [57], among others.

Despite the tremendous progress in research related to road dust over the past few decades, no bibliometric report has been documented on the quantity or trend of research, nor have the identities of prominent and prolific researchers in the field been revealed. Hence, the present study was carried out to evaluate the global trends in road dust research with the following objectives: (i) to determine the annual scientific publications from 1906 to 2020; (ii) to determine the most prolific authors, institutions, and countries; (iii) to identify relevant documents and sources in road dust research; (iv) to identify the common keywords and trending topics in the subject; and (v) to suggest possible future research directions for road dust research.

2. Materials and Methods

2.1. Search and Recovery of Data

The search and recovery of published documents on this subject were carried on the 6 July 2021 using Web of Science (WoS) and Scopus [58]. The WoS database covers the largest number of peer-reviewed publications on science and engineering, and it can serve for in-depth exploration of specialized or interdisciplinary fields [59], while Scopus is the widest citation and abstract database consisting of published literature [60,61]. These hybrid databases were employed in the study because of their ease of accessibility and wide coverage of a variety of disciplines [60]. Therefore, to retrieve data related to the subject, we used the following search keywords: TITLE: (road dust*) OR TITLE: (street dust*) OR TITLE: (traffic dust*) with the article search mode on the WoS database. Moreover, the search keywords:(TITLE (road AND dust*) OR TITLE (street AND dust*) OR TITLE (traffic AND dust*)) AND PUBYEAR < 2021 AND (LIMIT-TO (DOCTYPE, "ar")) were recovered on the Scopus database. The search with backdated data between 1 January 1906 and 31 December 2020 was employed for the bibliometric study to retrieve all related publications on the subject. The following documents types were not considered for export in this study: meeting abstracts, corrections, news items, letters, note retractions, and editorial materials [38,62]. Subsequently, documents comprising of articles, proceedings papers, and book chapters were exported for bibliometric analysis. A total of 900 documents were retrieved from WoS, while the search on the Scopus database generated 1091 documents. These data were obtained in Bibtext file format and subjected to bibliometric analysis using RStudio software. RStudio software (version 4.1.0) was employed in this study because it is available freely (<https://www.rstudio.com/>, accessed on 10 October 2021).

2.2. Processing and Transformation of Data

RStudio (version 4.1.0) software with a bibliometric package for visualization, tabulation, and systematic mapping of retrieved data was employed for data processing and transformation [63]. Because two different databases (WoS and Scopus) were employed for this study, the possibility of data duplicate was high; as a result, these duplicates of data were eliminated by merging the duplicate data using R codes "duplicated Matching (M, Field = "TI", tol = 0.95)", resulting in a total of 1186 publications from the two databases. Codes of analysis of research structure including most relevant keywords, most productive country, most relevant sources, annually generated publications, and most productive authors were recovered from <https://www.bibliometrix.org> (accessed on 10 October 2021). Web of country collaboration, top author's production output over the years, co-citation, and keyword co-occurrence was evaluated and viewed with two-way web algorithms of rectangular matrices.

3. Results and Discussion

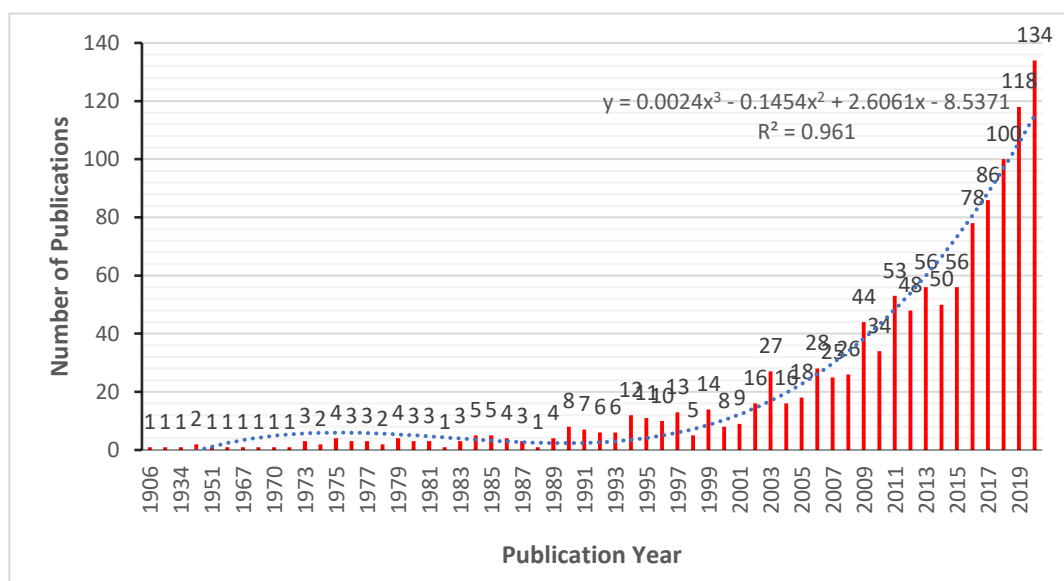
3.1. Publication Records of Road Dust Research

A total of 1186 publications from 380 journals and books with 2930 keywords (plus) (ID) and 2140 authors keywords (DE) (Table 1) were retrieved from the two databases (WoS and Scopus). Out of 2930 authors, 84 reported single-authored publications and 2865 reported multiple-authored publications, resulting in 2.47 author/publication and 0.405 publication/authors values, while the collaborative index was 2.6. This is an indication of the high engagement of multiple authors per publication, thus suggesting the productivity or enhanced interest in this field. For example, an increase in publications reported yearly suggests increasing interest in the field and vice versa. In this study, the number of publications reported was lowest in the year 1906 ($n = 1$) and highest in the year 2020 ($n = 134$).

Table 1. Publication record of studies on road dust recovered from Scopus and WoS databases from 1906 to 2020.

Publication Information	Records
Number of articles	1186
Sources (journals, books)	380
Keyword (plus) (ID)	2930
Author keywords (DE)	2140
Duration/period	114 years/1906–2020
Mean values of citation per publication	3.144
Authors	2930
Authors' appearances	5256
Authors of single-authored publication	65
Authors of multi-authored publications	2865
Single-authored publication	84
Publication per author	0.405
Authors per publication	2.47
Co-authors per publication	4.43
Collaboration index	2.6

Although there were few discrepancies in the number of yearly publications reported, a gradual increase in yearly publications was observed during the studied period (Figure 1). Moreover, the positive correlation ($y = 0.0024 \times 3 - 0.1454 \times 2 + 2.6061 \times -8.5371$; $R^2 = 0.961$) obtained when the data were fitted into a polynomial model indicates that more data or publications on this subject could be generated in years to come. It was also observed that scholarly works on road dust have been conducted in the domains of surveillance [29], source apportionment [64], distribution [65,66], and ecological toxicity [19]. The annual growth rate of 8.97% for published literature within this timeframe further confirms that research on heavy metal pollution in road dust has attracted attention over the years.

**Figure 1.** Annual publication record of studies on road dust from 1906 to 2020.

3.2. Contributing Countries

The top 20 leading countries on road dust research from 1906 to 2020 are presented in Table 2. Over 50 countries published reports on this research niche within this period. China, the USA, the United Kingdom, Iran, Japan, India, Turkey, Spain, Germany, and Poland were the top 10 countries with the most research documents on this topic. The publications of these countries accounted for 83.34% of the total publications across the globe. China was ranked first with 322 publications amounting to 36.45% of the total publications followed by the USA with 96 publications (10.87%) and the United Kingdom with 55 publications (6.23%). Furthermore, other countries within the top ten brackets include Iran with 48 publications (5.44%), Japan with 47 publications (5.32%), India with 46 publications (5.21%), Turkey (3.96%), Spain (3.74%), Germany (3.17%), and Poland (2.95%). However, there were slight alterations in ranking when productivity was assessed regarding the number of citations per country. China ($n = 9561$) and the United Kingdom ($n = 3384$) were the two nations with the highest numbers of citations (Table 2). Worthy of note is that no African country made the list of the top 20 nations with the highest number of citations. However, Bahrain ($n = 530$) and Jordan ($n = 525$) are the two countries in the Arabian Peninsula that made the top 20 list of nations with the highest citations, while the UAE, Kuwait, and Oman were not among the top 20 countries. These data are of concern considering the enormous levels of vehicular traffic, industrial emissions, and atmospheric pollution in these countries [67], and this underlines the need for research on this topic in Africa and the Arabian Peninsula. Equally, multiple-country publications and single-country publications, as well as their ratio, were assessed, and single-country publications dominated road dust research as shown in Table 2.

Table 2. Twenty most productive countries in road dust research and overall number of citations per country.

Most Productive Countries								Overall Number of Citations per Country			
Position	Country	Publications	%	Freq	SCP	MCP	MCP_Ratio	Position	Country	Total Citations	Average Citations
1	China	322	36.45	0.299257	282	40	0.1242	1	China	9561	29.69
2	USA	96	10.87	0.089219	82	14	0.1458	2	United Kingdom	3384	61.53
3	United Kingdom	55	6.23	0.051115	41	14	0.2545	3	Spain	3224	97.70
4	Iran	48	5.44	0.04461	30	18	0.375	4	USA	1938	20.19
5	Japan	47	5.32	0.04368	33	14	0.2979	5	Japan	1848	39.32
6	India	46	5.21	0.042751	39	7	0.1522	6	Iran	1495	31.15
7	Turkey	35	3.96	0.032528	34	1	0.0286	7	India	1159	25.20
8	Spain	33	3.74	0.030669	14	19	0.5758	8	Turkey	1113	31.80
9	Germany	28	3.17	0.026022	24	4	0.1429	9	Korea	790	43.89
10	Poland	26	2.95	0.024164	24	2	0.0769	10	Germany	765	27.32
11	Australia	23	2.60	0.021375	18	5	0.2174	10	New Zealand	765	191.25
12	Korea	18	2.04	0.016729	16	2	0.1111	12	Australia	755	32.83
13	Canada	17	1.93	0.015799	13	4	0.2353	13	Poland	658	25.31
14	Brazil	14	1.59	0.013011	13	1	0.0714	14	Greece	554	69.25
15	Italy	14	1.59	0.013011	10	4	0.2857	15	Italy	543	38.79
16	Nigeria	14	1.59	0.013011	13	1	0.0714	16	Bahrain	530	106.00
17	Jordan	13	1.47	0.012082	10	3	0.2308	17	Jordan	525	40.38
18	Sweden	12	1.36	0.011152	10	2	0.1667	18	Finland	376	41.78
19	Czech Republic	11	1.25	0.010223	11	0	0	19	Brazil	299	21.36
20	Malaysia	11	1.25	0.010223	9	2	0.1818	20	Argentina	246	41.00

SCP—single-country publications; MCP—multiple-country publications; MCP_Ratio—multiple-country publication per publication.

China was observed to be very dominant in all bibliometric indices, indicating the difference between the level of understanding/awareness of China and that of other countries/regions of the world regarding the danger and potential health effects of the exposure, inhalation, and ingestion of, as well as dermal contact with, road dust. For instance, Shi et al. [68] reported elevated concentrations of Pb, Cd, Cu, Ni, Zn, and Cr

(but not Mn) in street dust of Xianyang City, China, compared to background soil levels. The report of Yongming et al. [25] highlighted that in comparison with other Chinese soil, urban dust in Xi'an, China, has elevated metal concentrations, except for those of arsenic and manganese. This country has competent researchers and government research funds; hence, the researchers from different institutions within the country may collaborate, and they might not have any reasons to depend on researchers outside their own country for research grants, skills, and publications [69–71].

Examining the soil guideline values of China, Chen et al. [72] revealed that it was only Cd that had a considerable contamination level in roadside soils in Beijing, China, while those of Cu, Zn, and Pb were lesser, and As, Ni, and Cr was not detected at all. Similarly, studies conducted by Naderizadeh et al. [73] and Wei et al. [15] have also reported the presence of heavy metal (such as Pb, Cu, Zn, Cd, Cr, Ni, Mn, Be, Co, and U) in road-deposited dust in different types of urban environments. Lu et al. [26] reported that in comparison with Chinese soil guidelines, street dust in Baoji, China, has high heavy metal concentrations (Pb, Cu, Zn, Ni, and Mn). Similarly, Aslam et al. [67] documented heavy metals (such as Pb, Cd, Cu, Zn, Fe, Ni, and Mn) in different roads with varying levels of traffic lights throughout Dubai, the United Arab Emirates. In their study, higher concentrations of heavy metals in road dust with more traffic lights were reported. Moreover, in Bahrain, Madany et al. [74], documented the difference and similarities in the concentration of heavy metals in outdoor road dust and residential indoor dust. The mean concentrations of 742, 1.5, 67, 9.6, and 12 mg/kg, for Pb, Cd, Zn, Cr, and Ni, respectively, were obtained with the major source of metals being vehicle exhaust. In a similar study, Al-rajhl et al. [75] in Riyadh, Saudi Arabia, examined the correlation between metal levels and outdoor road-deposited dust and indoor dust. Heavy metal mean concentrations of 1762 ± 593 , 2.5 ± 0.3 , 443 ± 223 , 35.1 ± 2.7 , 93.9 ± 41.9 , 43.9 ± 5.6 , and 4.6 ± 0.3 $\mu\text{g/g}$, for Pb, Cd, Zn, Cr, Cu, Ni, and Li, respectively, were reported. These results indicate that dust samples from the road are heavily contaminated by heavy metals.

This study clearly revealed that about 60% of the research on road dust comes from developed countries, while low-income countries accounted for a few of the publications on this topic. The reason for this may not be far from the fact that most of the leading research laboratories, institutions, and centers of the world are located in these developed countries [76,77]. Other contributing factors may include adequate government funding, economic prosperity, presence of conducive and sophisticated research environments and laboratories, opportunities for research grants, and opportunities to enjoy short-term research and exchange programs in developed countries [57].

Nevertheless, it can be observed that countries with arid and desert environments in the Middle East (Jordan, Iraq, Oman, Qatar, United Arab Emirates, Yemen, etc.) and some African countries (Algeria, Egypt, Chad, Libya, Mali, Morocco, Niger, Sudan, Tunisia, etc.) facing serious dust pollution are not active in this research area. However, one of the possible reasons that could have prevented African countries from participating in this research is the lack of research funds and support from the government. On the contrary, in the Middle East, research funds might not be the problem, but poor visibility in this research domain could result in it being deemed a low priority.

3.3. Research Collaboration and Institutions

Collaboration is an essential part of scientific research, and different patterns of collaboration both shape scientific productivity and characterize individual scientific fields [78]. Research collaboration has been observed to be gaining huge attention amongst scientists worldwide because of the enormous advantage inherent in this research initiative. These advantages include, among others, prompt delivery of research output, improved research quality and output, exchange of research ideas and technology, improved research productivity, and access to human resources and research facilities [79,80]. Moreover, this research initiative permits the joint applications of research funds, the establishment of novel research projects, etc. Collaborations increase the citations of papers, especially if

there is an international team of authors involved [81]. Scholars must recognize the value of research networking for the goal of increasing productivity, as association with experts in a field bring about creative and innovative thinking and ideas. Therefore, collaboration should be the aim of every researcher and institution because it enables capacity building and offers multiple opportunities to surpass limitations that arise within a single institution and due to scarce resources [82]. As a result of the numerous advantages of collaboration, funding bodies, including government agencies, industries, and research institutions, are encouraging collaborations within the scientific communities by deliberately including the clause for research collaboration in their calls for grants before researchers can access their funds/grants [57].

Enhanced access to sophisticated and hyphenated analytical instruments and the availability of reference standards for metals and solvents are another important reason for collaboration on research related to heavy metal burdens in road dust. In the present study, although a total of 1186 publications were retrieved from the two databases (WoS and Scopus) on road dust, the top 20 countries generated 883 publications out of which 726 publications (82.22%) were from a single country and 416 publications (17.78%) involved inter-country publications (Table 2). For example, China reported 282 single-country publications and 40 multiple-countries publications, the USA published 82 single country papers and 14 inter-country research documents, and the United Kingdom reported 41 intra-country research documents and 14 inter-country publications. Surprisingly, there were no countries located in the Arabian Peninsula among the top 20 countries with the most collaborations on road dust research as single-country publications or multiple-country publications.

Figure 2 depicts research collaborations on road dust research among the top 20 countries. Lines are routes that connect these countries and are employed for knowledge map visualization [83]. The line connections represent the number of collaborations among countries and the line thickness indicates the strength/frequency of the collaboration. It is evident from Figure 2 that China and the United Kingdom were the countries with the highest collaboration on the subject with 21 connection lines each to other countries. China's strongest connection was with the USA, Canada, Germany, and Australia. The USA (with 20 connection lines) had the third highest collaborative strength. The collaborative advantage of China over other countries of the world other than the United Kingdom may be related to the setting up of different funding and travel schemes/programs by the Government of China for Chinese scientists. Examples of these schemes/programs are the "Framework Program" and "Thousand Talent Program, Horizon 2020"; these are programs financed by both China and the European Union (<https://www.enago.com/academy/chinese-scientists-increase-global-research-collaboration/>, accessed on 13 October 2021).

The most relevant institutions in road dust research are presented in Figure 3. Our analysis revealed that the University of Tokyo, Japan, is the most productive institution on road dust research with 36 publications. Shaanxi Normal University, China, and the University Nacl Autonoma, Mexico, were ranked second and third with 24 and 22 publications, respectively. The fourth- and fifth-ranked institutions in road dust research are Shiraz University, Iran ($n = 21$), and Beijing Normal University, China ($n = 20$). These institutions make up the five most productive institutions on road dust research globally, and they accounted for 38.80% of the first twenty institutions with the highest publications on road dust-related research indexed in both Scopus and WoS databases. It can be observed that the Chinese institutions dominated the top twenty institutions in regard to road dust research (Figure 3), and this result corroborates our observations of some of the bibliometric indices previously reported in Figure 1.

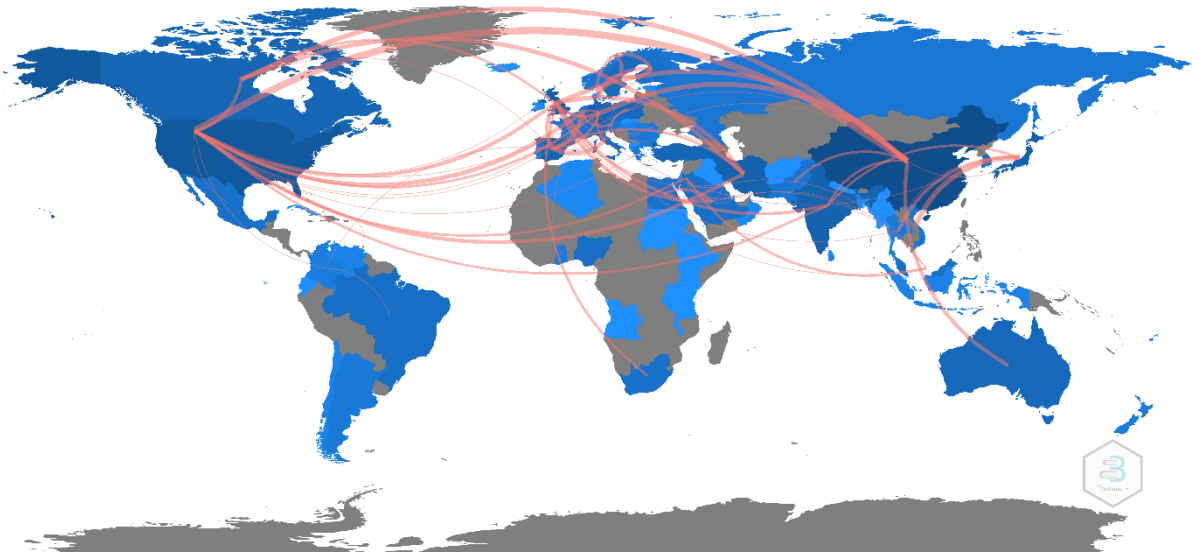


Figure 2. Collaboration visualization map of the top 20 countries researching road dust (lines connecting countries indicate frequency of collaboration and line thickness shows strength of collaboration).

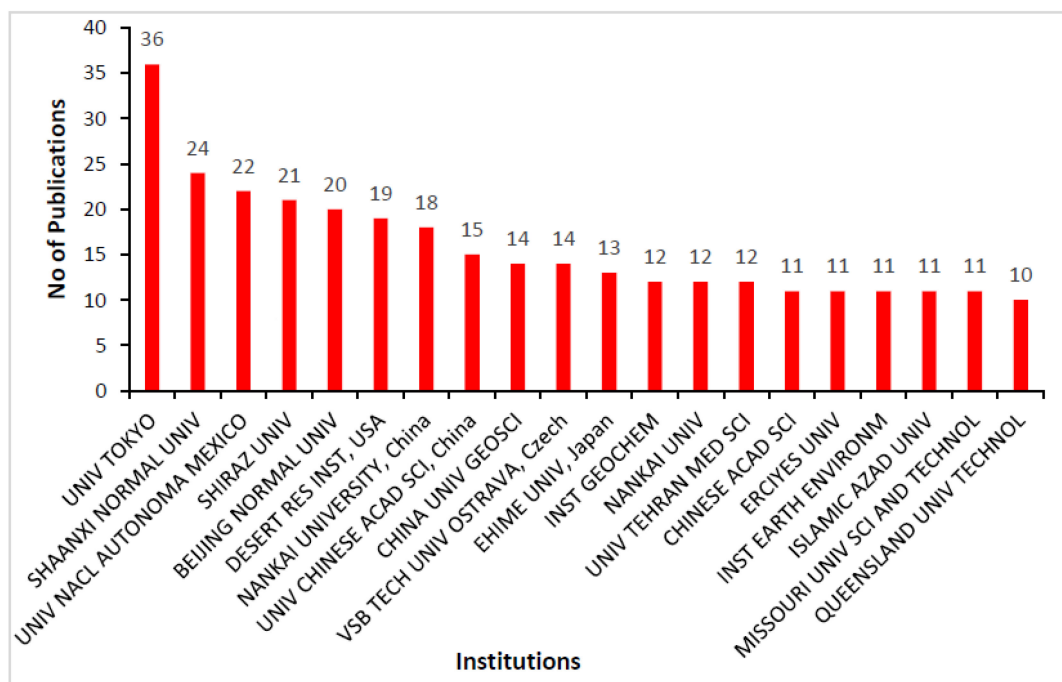


Figure 3. Top 20 research institutions in regard to road dust research from 1906 to 2020.

3.4. Analysis of Keywords

Table 3 presents a list of keywords related to research on road dust. It can be observed that author keywords were employed to assess the trend in research associated with road dust. This analysis is important as keywords in scientific publications are used to determine the state of a research area. In addition, it can be used as an indicator of the research hotspot in a given field [77]. In addition, keywords help to identify relevant themes in research publications. This is the reason editors of journals require authors to include in their manuscripts five to seven keywords before submission of their papers for peer review. In this study, the relevant themes related to this research area, including road dust, street dust, heavy metal(s), dust, health risk assessment, pm10, PAH, health risk, pollution, and source apportionment, are presented in Table 3. The keyword with the highest citation

was road dust, showing up in 280 publications. Street dust showed up in 223 publications in the keywords, while heavy metals was observed in 125 publications. The term “heavy metals” over the past 20 years has been consistently employed in various articles and reports relating to chemical hazards and safe handling of chemical compounds. It is usually referred to as the group name for metalloids and metals that are linked to pollution and that have toxicity potential [84].

Table 3. Top 20 most relevant keywords in studies related to road dust from 1906 to 2020.

S/No	Keywords	Occurrence
1	Road dust	280
2	Street dust	223
3	Heavy metals	125
4	Heavy metal	77
5	Dust	65
6	Health risk assessment	53
7	PM10	50
8	PAHs	49
9	Health risk	38
10	Enrichment factor	33
11	Risk assessment	32
12	Pollution	30
13	Metals	29
14	Soil	27
15	Source apportionment	24
16	Air pollution	23
17	Spatial distribution	22
18	Traffic	21
19	ICP-MS	20
20	Polycyclic aromatic hydrocarbons	20

The quantitative method for metal analysis is the digestion method and, thereafter, measurement using an atomic absorption spectrophotometer (AAS) [85]. In addition, many other instruments, including the inductively coupled plasma optical emission spectrophotometer (ICP-OES), which has the advantage of analyzing various metal analytes at the same time with high sensitivity, have also recently been explored. Despite the availability of these instruments and their potential, their inability to detect heavy metals at extremely low concentration limits and the isotope composition of elements is a major drawback of these instruments [56]. To overcome the drawbacks inherent in AAS and ICP-OES, the inductively coupled plasma mass spectrophotometer (ICP-MS) is currently being explored. This instrument has demonstrated the capability to detect and quantify elements with extremely low concentrations [86]. This may explain the occurrence of “ICP MS” ($n = 19$) in the top twenty list of keywords found in this study.

To comprehend the evolution of research on road dust over time, the different keywords during different time intervals were evaluated in the ranges of 1906–2005, 2006–2012, 2013–2016, 2017–2019, and 2020–2020 (Figure 4). It was observed that before 2005, research on road dust was mainly focused on air pollution and dust generally. ICP-MS, PM10, PAHs also dominated this period. Between 2006 and 2012, the research focus was limited to dust from roadsides as inferred from the dominance of keywords such as street dust, road dust, PM10, ICP-MS, trace element, air pollution, metals, and sources. In addition, from 2013 to 2016, road dust and street dust, heavy metals, spatial analysis, enrichment factors, and trace elements were dominant keywords during this period. This is an indication that focus on this type of study has now been streamlined to the detection of heavy metals as a pollutant type in road dust. Moreover, analysis of the presence of heavy metals in road dust was observed during this period. Between 2017–2019 and 2020, the analysis of heavy metals in street dust became very prominent, as these keywords, as well as their source identification and spatial analysis, were observed to take the lead during these peri-

ods. Other keywords observed during these stages include PM10, PAHs, urban pollution, optimization, and bioaccessibility.

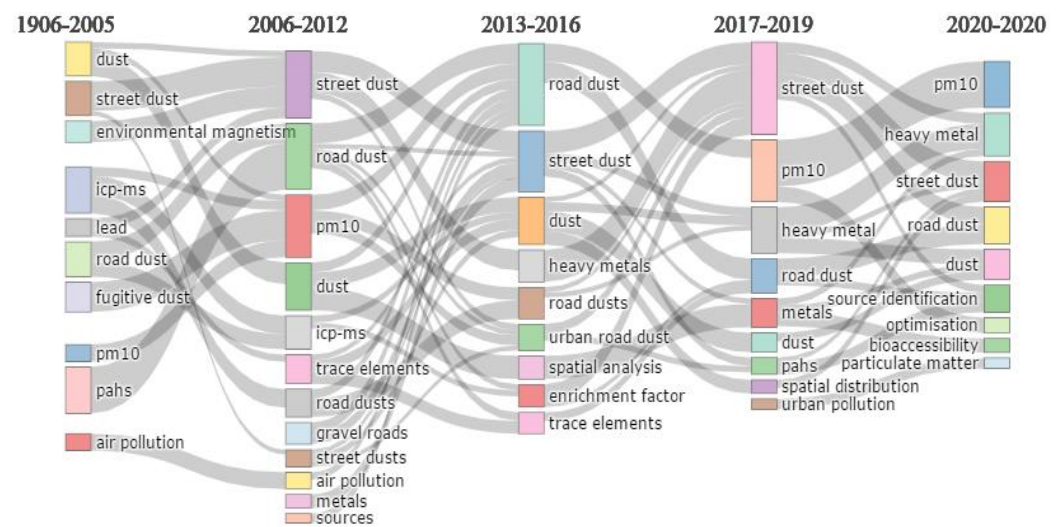


Figure 4. Thematic evolution of research on road dust during different time intervals.

3.5. Journals' Contribution

The diversity of journals with publications of research on road dust is an indication of the attention this research topic is gaining across different research lines. Examining the research areas of the 20 topmost journals, it can be observed that environmental science journals mostly dominated and ranked first place with 445 publications. Only two ecotoxicology journals were found (Figure 5). The 20 topmost journals accounted for three-quarters of the overall publications ($n = 951$, 78.21%). *Science of the Total Environment* with a Thomson Reuters 2020 impact factor of 7.963 ranked first place in published articles on this topic ($n = 87$, 16.05%) followed by *Atmospheric Environment* with a 2020 journal impact factor of 4.798 ($n = 63$, 11.62%). Among the 20 topmost journals, the *Journal of Hazardous Materials* had the highest impact factor in 2020 with 10.588, and five other journals had an impact factor between 6.00 and 10.00, namely, *Science of the Total Environment* (7.963), *Environmental Pollution* (8.071), *Chemosphere* (7.086), *Ecotoxicology Environment Safety* (6.291), and *Environment International* (9.621). Careful consideration of the publishers of the journals within the 20 topmost journals revealed that Elsevier and Springer publishers reported 40% and 35% of the studies on this topic, respectively. Taylor and Francis and MDPI both published 5% of the studies in this field.

It is worth mentioning that road dust research has received enormous attention in high-impact factor, multi-disciplinary and environmental science journals devoted to publishing novel and high-quality research. The journal in which a paper is published has a significant influence on its citations. Most researchers always try as much as possible to publish in a good journal; however, it is important to highlight the article processing charges of these high-quality journals. Some institutions do not have funds that could cater to publication charges, and, hence, the researchers end up publishing their papers in non-open-access journals. Accessibility of these papers published in non-open-access journals by researchers would depend on the institutions' subscription to those journals. Papers published in open-access journals usually receive more citations than those published in non-open-access journals, and these citations influence the impact factor of a journal. The impact factor is usually calculated every year as the ratio of papers published in a journal in the previous two years over the citations received within that period [87]. Popular sources and other trends in a research area during a certain period can be easily identified and can provide a reliable reference for researchers [88]. Furthermore, core journals provide a significant amount of information, which is helpful when searching for documents or submitting research achievements [89]. The active performance of these journals in this field can

increase their ranking, thereby facilitating further publication of related papers in these journals in the future.

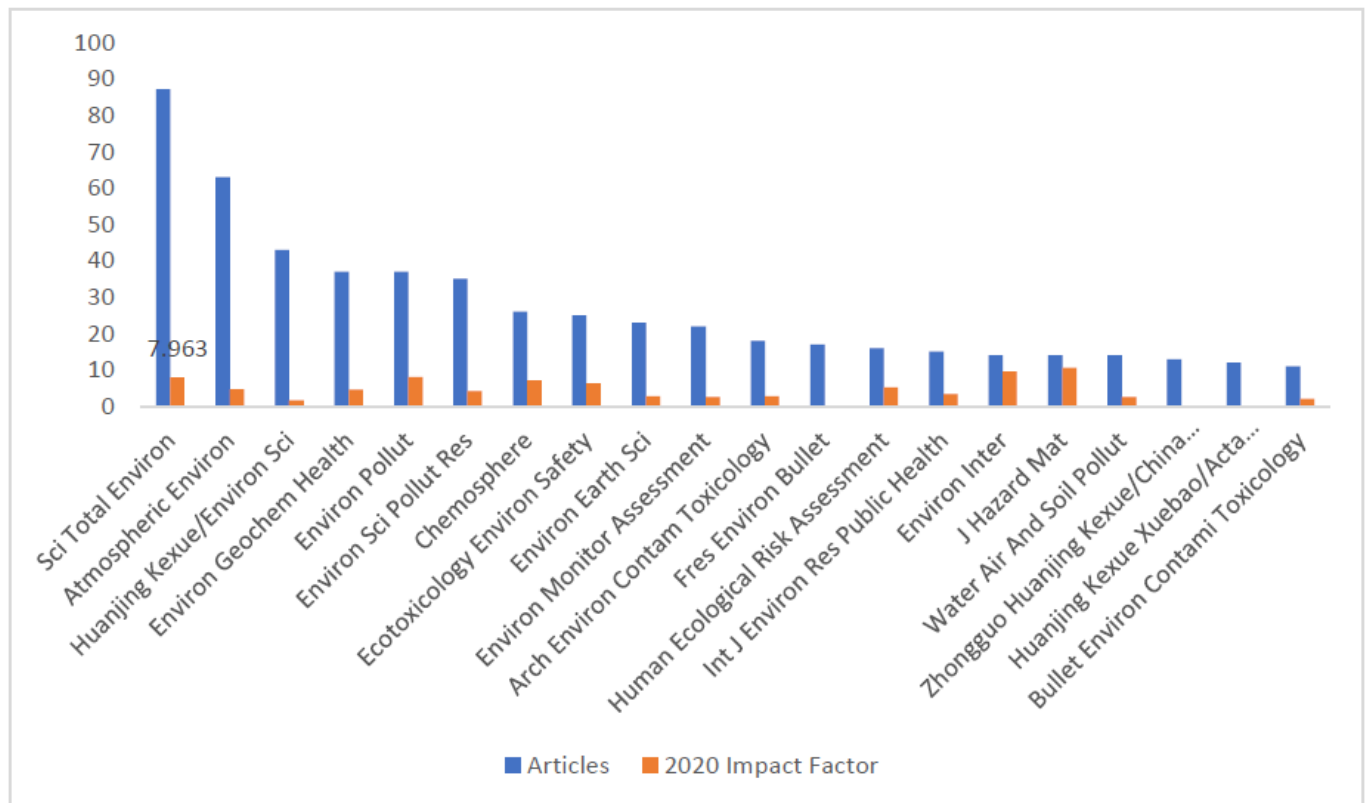


Figure 5. First 20 journals with the highest publications in studies on road dusts and their 2020 impact factors (IF) according to Thompson Reuters.

3.6. Most Productive Authors

This section presents the most prolific authors in terms of the number of articles published in the field of road dust pollution. Research only achieves its goal when it is shared, i.e., when an author finds an audience who values their ideas and findings. Nowadays, a reader's interest can be measured in terms of the number of views that an article receives and citations of the article. According to a report documented by Garcia et al. [90] "the validation of a research, its legitimization, and acknowledgment, depends on the reader's judgment relating to the text which can be measured by the rate and, most importantly, by its citation in other works". In the present study, Table 4 shows the first twenty most productive authors studying road dust in urban environments. The most productive author was Li X with 28 publications, followed by Li Y (24 publications), Zhang J, and Lu X, (22 publications). Other authors in the first twenty positions include Wang Y ($n = 18$), Querol X ($n = 17$), Zhang Y ($n = 17$), Keshavarzi B ($n = 16$), Yang Y ($n = 15$), Moore F ($n = 15$), Furumai H ($n = 14$), and Liu J ($n = 14$). The author citation index shows that Harrison R had the most citations, with 1486 citations, followed by Li X with 1338 citations and Amato F in third place with 1301 citations. A more significant index that must be considered is the authors' publication output over the years, as depicted in Figure S1 of Supplementary Materials. In Figure S1, the blue nodes indicate the author's productivity in a calendar year, while the threads holding the blue nodes signify consistency in the research output of each author on the subject over the years. The larger the blue nodes, the more productive an author is in a particular year. It can be observed that Li X has been consistent over the years in the publication of research works on road dust, with more nodes held together by a thread. Larger nodes indicate a greater number of articles in a particular year. This author had the single-year highest publication output

in 2009 and 2016. Zhang J contributed the first publication on this topic in 2006 and had the single-year highest publication in 2019. From this analysis, it was observed that Li Y was the author among the top 20 authors with the most productive articles within the survey period and with the highest single-year publication output recorded in 2017 with 13 publications. This result shows that Chinese authors dominated the ranking of the 20 topmost authors. Generally, authors from China topped the list when each author's total number of publications, h-index, and total citations were combined. The impact of an author in a particular field cannot be determined by only the number of their publications or the number of citations received; an author's level metrics such as their h-index, g-index, and m-index, are often used to obtain a more objective view of their impact [91].

Table 4. Top 20 most productive authors based on number of publications and total number of citations.

Rank	Author	NP	h_Index	g_Index	m_Index	TC	PY_Start
1	Li X	28	12	28	0.571	1338	2001
2	Li Y	24	11	24	0.846	787	2009
3	Lu X	22	15	22	1.154	1164	2009
4	Zhang J	22	10	18	0.625	334	2006
5	Amato F	20	16	20	1.231	1301	2009
6	Wang Y	18	11	18	0.733	656	2007
7	Querol X	17	14	17	1.077	1243	2009
8	Zhang Y	17	10	17	0.909	551	2011
9	Keshavarzi B	16	12	16	1.714	785	2015
10	Yang Y	15	13	15	0.481	744	1995
11	Moore F	15	11	15	1.571	644	2015
12	Furumai H	14	12	14	0.667	408	2004
13	Liu J	14	10	14	0.833	806	2010
14	Nakajima F	14	10	14	0.556	316	2004
15	Wang L	14	10	14	0.667	1207	2007
16	Alastuey A	12	12	12	0.923	1158	2009
17	Egodawatta P	12	9	12	0.9	395	2012
18	Harrison R	11	11	11	0.239	1486	1976
19	Etyemezian V	11	10	11	0.526	475	2003
20	Gillies J	10	9	10	0.391	530	1999

NP = number of publications; TC = total citation; PY_Start = author's first publication year.

The h-index, as an indicator for assessing the quality of scientific output, is commonly used to calculate both the productivity and citation impact per author or group of authors belonging to an institute or country [92]. The h-index is an accurate reflection of the academic contribution and achievement and is applied in many bibliometric analyses [93]. However, the h-index is not suitable for comparing interdisciplinary fields [94]. This is a reflection of the high amount and quality of work on this subject from China. This also shows that scientists in China have conducted an immense amount of studies on road dust. Conversely, no authors from the countries of the Arabian Peninsula and Africa were found in the top 20 most productive authors on research in this subject, and this is probably a reflection of the difference between the level of understanding of researchers from China and that of those from other parts of the world regarding the dangers posed by the impact of road dust pollution on the environment by researchers.

3.7. Most Cited Documents

Citations are generally employed as performance monitors/indicators in research and within the research environment [95]. Occasionally, they are considered as good indicators of the quality and impact of research [95]. The influence of a scientific publication on research is a reflection of the number of citations generated by that publication [96]. On the other hand, the amount of citations of a published paper can also bring about constructive criticism of the study. Moreover, there is a bias in some quarters for publication citations because many argue that citation is a function of time and accessibility to literature [97].

In this study, the top 20 most cited documents on road dust research are presented in Table 4. The global citation refers to the total number of citations a document received from other documents within and out of the same collection, while the global total citation per year is the total number of citations the documents received divided by the number of citable years. The extent to which a document is cited by others reflects its influence on the research landscape in a given field. Certain documents may serve as a source of a meaningful methodology, excellent background, and useful discussions for other researchers [98]. The most cited article on this subject placed first and the least cited placed last. The report of “Li XD, 2001” received the highest citation, with 738 citations and 35 citations per year. Publications reported by “Rogge WF 1993” and “Ferreira-Baptista L 2005” with 600 and 599 citations are ranked second and third, respectively. The most citation gathered by the report of “Li XD, 2001” could be due to the critical discussion of heavy metal contamination in road dust, urban soils, and agricultural soils in Hong Kong. Moreover, the type of dust and soil samples as well as the environmental matrices considered for discussion in this study and the variety of parameters, including a discussion of the concentrations, levels, potential ecological implication, sample collection, and analytical techniques for heavy metal determination, may be responsible for the huge number of citations accrued by this publication. Environmental-related journals were observed to have reported 90% of the top 20 most cited publications, while only 10 journals published all of the articles within the top 20 most cited publications. This reflects authors’ preference of journal type. Although publications before the 20th century accrued citations over time, the publications from the 20th century dominated the top 20 most cited studies (See Table 5).

Table 5. Top 20 publications with most citations in road dust research from 1906 to 2020.

First Author and Publication Year	Journal	DOI	Total Citations	TC per Year	Normalized TC
Li XD, 2001	<i>Appl Geochem</i>	10.1016/S0883-2927(01)00045-2	738	35.1429	5.2217
Rogge WF, 1993	<i>Environ Sci Technol</i>	10.1021/es00046a019	600	20.6897	3.5191
Ferreira-Baptista L, 2005	<i>Atmos Environ</i>	10.1016/j.atmosenv.2005.03.026	599	35.2353	8.1312
Harrison RM, 1981	<i>Environ Sci Technol</i>	10.1021/es00093a013	493	12.0244	2.9819
Zheng N, 2010	<i>Sci Total Environ</i>	10.1016/j.scitotenv.2009.10.075	480	40	9.3471
Demiguel E, 1997	<i>Atmos Environ</i>	10.1016/S1352-2310(97)00101-5	413	16.52	7.8609
Charlesworth S, 2003	<i>Environ Int</i>	10.1016/S0160-4120(03)00015-1	364	19.1579	4.8944
Amato F, 2009	<i>Atmos Environ</i>	10.1016/j.atmosenv.2009.02.039	358	27.5385	5.5251
Banerjee ADK, 2003	<i>Environ Pollut</i>	10.1016/S0269-7491(02)00337-8	340	17.8947	4.5717
Lu XW, 2009	<i>J Hazard Mater</i>	10.1016/j.jhazmat.2008.04.052	310	23.8462	4.7843
Christoforidis A, 2009	<i>Geoderma</i>	10.1016/j.geoderma.2009.04.016	308	23.6923	4.7534
Lu XW, 2010	<i>J Hazard Mater</i>	10.1016/j.jhazmat.2009.09.001	304	25.3333	5.9198
Fergusson JE, 1991	<i>Sci Total Environ</i>	10.1016/0048-9697(91)90376-P	290	9.3548	2.5062
Sezgin N, 2004	<i>Environ Int</i>	10.1016/S0160-4120(03)00075-8	289	16.0556	3.6182
Amato F, 2009	<i>Atmos Environ-A</i>	10.1016/j.atmosenv.2008.12.009	277	21.3077	4.275
Duong TTT, 2011	<i>J Environ Manage</i>	10.1016/j.jenvman.2010.09.010	276	25.0909	6.1695
Fergusson JE, 1991	<i>Sci Total Environ</i>	10.1016/0048-9697(91)90376-P	270	8.7097	2.3333
Apegyei E, 2011	<i>Atmos Environ</i>	10.1016/j.atmosenv.2010.11.015	262	23.8182	5.8566
Saeedi M, 2012	<i>J Hazard Mater</i>	10.1016/j.jhazmat.2012.04.047	256	25.6	7.0177
Gietl JK, 2010	<i>Atmos Environ</i>	10.1016/j.atmosenv.2009.10.016	247	20.5833	4.8099

TC = total citation.

3.8. Implications of Road Dust Research on Micro-Organisms and Environmental Health

This present study shows that other than heavy metals, PAHs have been increasingly reported in street dust, and other contaminant types of biological origin, including micro-organisms, have been scarcely reported. Furthermore, the effect of road dust on microbial organisms and vegetation is a concern and requires more attention. In addition to particle size, exposure parameters and the relative bioavailability of heavy metals in street dust are important factors that affect health risk assessment [99]. However, bibliometric data obtained on this subject from our study cannot sufficiently represent the different factors affecting health risk assessment. Deviations in these parameters may result in huge errors in our overall metrics on health risk assessment. Moreover, there is a consensus in the

literature evaluated in this study that exposure to road dust significantly causes adverse health problems in humans, such as respiratory diseases and allergies [100].

3.8.1. Research on Microbiology and Infectious Disease in Relation to Road Dust

Research examining the relationship between microbiology and infectious diseases and road dust remains in its infancy. Few works related to microbiological endeavors in road dust research include the bioremediation of heavy metals in urban road dust using *Shewanella oneidensis* [101]; microbial biodegradation of road dust suppressant acetate in the assessment of its ecotoxicological safety; and microbial compositional assessment of road dust, which revealed pathogens such as *Bacillus subtilis* spores, wood-rotten fungi, and other biological aerosols [102]. Moreover, Woinska and Godlewska-zylkiewicz [103] achieved separation of platinum and palladium from road dust on immobilized fungi (*Aspergillus niger* and *Saccharomyces cerevisiae*), while Godlewska-zylkiewicz and Kozłowska [104] reported solid-state recovery of palladium in road dust using immobilized *Saccharomyces cerevisiae*. Ram et al. [105] reported that elemental constituents in road dust adversely affect phylloplane microflora in *Polyalthia longifolia*, and this might have strong implications for plants and overall productivity. In addition, the report observed the absence of fungal phylloplane microflora, probably due to the presence of toxic elements, including As and Hg, in road dust deposited on leaf surfaces [105].

Meanwhile, road dust, similar to most environmental niches, is rich in microbial diversity, but the role of road dust in the spread and epidemiology of microbial infections and related diseases is an invaluable topic that has not been well explored. Different pathogens have been isolated from house dust, including *Streptococcus pneumoniae*, *Bacillus licheniformis*, and *Neisseria meningitides* [106,107]. Similarly, various microbial compounds, such as bacterial 3-hydroxy fatty acids, muramic acid (MuA), endotoxin/lipopolysaccharide (LPS), fungal ergosterol, and both culturable and non-culturable microbes, have been detected in road dust [108]. Thus, it can be suggested that road dust is a potential reservoir of pathogenic microbes in the environment deserving extensive investigation, and this is a subject currently being pursued by our research group.

3.8.2. Adverse Effects of Road Dust on Vegetation

Vegetation improves the quality of air by absorbing carbon dioxide and emitting oxygen. The vegetation acts as a sound barricade and is important for scenic beauty and safety [109]. Roadside vegetation is the key recipient of road dust deposits, as it acts as the first line of defense against urban dust pollution [110,111]. Exposure to road dust has detrimental effects on human health [100,112] and vegetation [111,113]. Dust particles cover the leaves and block stomatal opening, which consequently prevents gas exchange and water in the atmosphere [114,115]. Trees growing along the roadsides have been reported to exhibit several morphological, biochemical, and anatomical changes because of higher concentrations of dust pollutants [111]. However, some trees have been reported to tolerate higher concentrations by modulating their physiological and biochemical traits. In addition, sunlight required for photosynthesis is unable to reach the leaf, and this affects normal physiological and biochemical processes of the plant, such as chlorophyll degradation, which can lead to necrosis and inhibit growth [116]. The adverse effects of heavy metal content in dust particles on vegetation have also been reported in the literature [117]. However, the dust tolerance of a plant depends on several factors, such as leaf geometry, leaf phyllotaxy, leaf structure, leaf epidermal, height and canopy of trees, and cuticular features [118]. The report of Farmer [119] highlighted that dust particles increase leaf temperature by decreasing diffusive resistance, and this makes the leaves susceptible to drought. In addition, dust particles on leaves permit easy penetration of road salt, and this consequently leads to water stress in a plant [120]. Hence, optical features of leaves, particularly the surface reflectance in the visible and shortwave infrared radiation range, are altered due to surface dust deposits [121]. Unfortunately, most of the studies on road dust have only focused on its adverse effects on humans and the ecosystem, and

there remains a scarcity of information about the beneficial effects of chemical constituents in dust particles on the soil and vegetation.

Most researchers in this field have focused on the adverse effects of road dust deposits. However, few studies have revealed that atmospheric deposits have a great influence on the nutritional status of the ecosystem [122,123]. As a result, some of these elements have been studied in this regard; however, N and P have received special attention because of their significant impact on plant growth [124]. The amount of nutrients released from the atmospheric deposit to the ecosystem depends on the capacity of the plant nutrient uptake and soil nutrient contents, among other factors. Furthermore, Kome et al. [125] emphasized in their report that clay can improve the nutrient- and water-holding capacity of soils and increase their fertility, and this is in accordance with the findings of Newman [126], who emphasized that the nutrients in dust deposits can enrich soils with low nutrient contents and improve soil fertility with a significant increase in vegetation productivity. Furthermore, granites used in road construction contain some important chemical substances that can enrich soils and improve the growth of roadside vegetation when released through dust particles to the environment. Nevertheless, there is a dearth of studies in the area of examining the beneficial effects in terms of nutrition that the chemical substances in road dust deposits may have on the roadside vegetation and soil, and, hence, researchers in this field are encouraged to explore this topic in their future studies.

3.8.3. Study Limitations

Since this study employed and relied on published information from databases in the scientific domain and analyses of data processed using the bibliometric framework, limitations could not be avoided. Two databases (WoS and Scopus), as well as only papers published in English, were employed in this study, and, therefore, future studies should consider including other databases and non-English language publications to accommodate other articles that might greatly influence the bibliometric results of this subject matter. Despite such limitations, this study will aid researchers intending to identify hotspots and areas in need of research in this field as well as those with the aim of determining influential papers and authors in this research niche.

4. Conclusions and Future Prospects

The present study provides an overview and describes the trend of scientific research output on road dust from 1906 to 2020. The bibliometric analysis was comprehensive and relatively objective based on the data retrieved from the two databases used in the study. Our findings revealed a significant growth in the research output over the years, and research interest in the subject was noted to have risen drastically as compared when this research subject was in its infancy. Interestingly, road dust research has received enormous consideration in some high-quality scientific domains, and we noted that there was a strong single-country publication tendency among researchers as compared to multiple-countries publications. Similarly, it was observed that Japanese and Chinese institutions and academics dominated research in this field, and the two prominent leading countries were China and the United Kingdom. The engagement of researchers from these world leaders in this field has been directed toward the common goal of solving environmental issues caused by road dust deposits, focusing especially on their adverse effects on public health and the ecosystem. Literature data retrieved from this study suggest that heavy traffic urban regions are more exposed to contamination from road dust. Moreover, major studies on this subject have been carried out in developed nations, and only a few have been published in low-income countries. Countries located in the Arabian Peninsula and Africa have barely contributed to the research field of road dust, despite the fact that this research topic should be of priority considering the peculiarity of their geography and climate. We are optimistic that this report will be a good impetus to encourage interest in road dust research, setting up new sites, and enlarging the framework of research in these regions in the future.

Our findings suggest that future research should also focus on determining the levels and fate of contaminants, such as hydrocarbons and microbial diversities, in road dust, even in countries that have extensively studied this subject and those that have seldom reported research in this field. Furthermore, most countries do not have standard regulations for heavy metal and other contaminants limits in road dust, as most researchers have only compared results from this subject with heavy metal concentrations in soil and sediments from areas other than road or street dust. Therefore, this calls for concerted efforts and a greater amount of research to arrive at the acceptable limits for contaminants in road dust. Future research should promote partnerships and employ real-life results to generate a comprehensive database on the permissible level of heavy metals and other contaminants in road dust. This will not only enhance science and community engagement and communication but will certainly improve public awareness of the burdens of road dust.

Although over the years, the focus of researchers has been on the adverse effects of heavy metals and related substances in road dust on humans, animals, and vegetation, no single study has reported on the nutritional benefits of chemical substances, such as nitrogen (N), phosphorus (P), and total organic carbon (TOC), in road dust deposited near vegetation and soil. Therefore, these researchers in the field should actively focus on this topic in the future. Similarly, research regarding the relationship between microbiological and infectious diseases and road dust is still in its infancy, but evidence suggests that road dust is rich in pathogenic microorganisms, such as bacteria, spores, protozoa, fungi, and viruses. This study revealed that there remains a lack of research attention given to the role of road dust-borne pathogens. The role of road dust in the spread and epidemiology of microbial infections and related diseases is an invaluable topic that needs to be explored for sustainable public health in relation to respiratory infections and diseases. Moreover, this study suggests cleaner and sustainable practices, such as the collection and recycling of road dust for construction purposes and extractive recovery of road-dust-associated metals.

Supplementary Materials: The following are available online at <https://www.mdpi.com/article/10.3390/su132011516/s1>, Figure S1: Top authors' publication output on road dust research over the years.

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