Bibliometric analysis of the study on exposure evaluation to aerosol nano or ultrafine particles in the breathing zone

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Abstract. To map the advancement of exposure evaluation research for particles less than 100 nm in the breathing zone, we developed a bibliometric analysis using VosViewer 1.6.15 by collecting relevant publications from Scopus on August 10th, 2020. Of 769 relevant documents, 90.64% (n = 697) came from the journal and used English as the language that started to be published in 1985. The results showed that research themes have grown on the three clusters related to inhaled nanoparticles exposure measurement, responses and effects, and their primary existence in consumer products. Moreover, depth analyses by visualizing maps of the top active countries, authors, and top-cited documents on the citation, co-citation, or co-occurrence have revealed several essential pieces of information on this research area. Our findings suggest that the greater depth on appropriate devices for exposure measurements, particularly in nano-sized, which matches with the metrics were needed. Through these efforts, the capabilities of analyses can improve for future inhaled nanoparticles exposure assessments.

1. Introduction

Regarding the development of nanotechnology, nanomaterials' use implies that the risks of particle less than 100 nm had spread to large environments, from workplaces as the production site until consumers in many forms of product. Previously, the sources of the general size-segregated particles from the combustion activities have also played as the contributors to the emission of nano or ultrafine particles, such as forest fires, volcanic eruptions, industrial chimneys, the exhaust of vehicles, and kitchens. Therefore, studies on the health effects of nano-sized particles have been extensively developed in the last two decades with nanotoxicological knowledge's critical role to comprehend the responses and make the adverse impacts identified in a more broad aspect [1-3]. Regarding the health and environmental risks, nanotechnology products, as the new contributors of nano-sized particles with combustion activities previously, need to concern for sustainable principles. While, the particulate matter in their size-segregated forms has been known can increasing respiratory morbidity and mortality [4,5].

Compared to the larger particles, nano-sized particles had more deposition rate to cross the pulmonary epithelium and reach the interstitium, which can be systematically distributed into the bloodstream to increase the possibility of increasing the level of inflammation [6,7]. Therefore, future effects of nano-
sized particles could be spread into other organs by their mechanism and ability, which have not anticipated today. Since the two most critical things were the hazard and exposure aspects in evaluating their health or environmental risks [8], nanoparticles' routes as pollutant exposure have been still challenging. In contrast, nanomaterials' identifications of chemical and physical characteristics describing the hazard can be handled and even relied on the exposure routes [9]. Of the inhalation, ingestion, skin uptake, and injection as the routes of nano or ultrafine particles enter the human body, inhalation was the most primary potential route and still required future researches.

In order to comprehend the development of knowledge in explaining some problems on personal nanoparticle exposure evaluation research from time to time, the review studies have been applied. Some achievements to show a new perspective in the general frameworks were addressed. Besides Oberdorster et al. (2005), which found the importance of expanding nanotoxicological studies to improve health impact analyses of nanoparticles [2], other critical review studies have contributed to being an essential reference and became the foundation for the next researches [10-12]. Monn (2001) has explained the crucial position of personal exposure on ultrafine particle measurement related to health that has encouraged other researchers to consider it. Meanwhile, Maynard & Aitken (2007) observed physical/chemical structure related to metrics that play an essential role in evaluating potential effects for engineered nanoparticles, then suggested all three metrics, particle number, surface area, and mass concentration, to measure. Moreover, Asbach et al. (2017) also summarized that airborne agents need to be measured in the personal exposure setting with the combination of metrics. Recently, this tool still needs to be developed.

However, those studies gave insight into one or some perspective on evaluating nanoparticle exposure in the breathing zone. The evolution of researches on this field comprehensively still requires more understanding to have what is obtained and developed to date. For this purpose, the bibliometric study, which could figure out fastly and precisely the critical points and aspects, has become an essential tool to evaluate and quantify the literature growth on a particular subject. In a given period, massive information was used. Therefore, bibliometric analysis through the statistical and visualization approach by applying some domains mathematically and continues developed to be well-established to reveal the research outputs [6,13,14] can be reliable for mapping the growth and development of exposure evaluation to nanoparticle studies in the breathing zone.

Recently, based on the Scopus database, it can be found that the bibliometric study has developed per year started from 2008 or 2009 with more than 100 publications and continued to increase massively. While it has been studied since 1972, the bibliometric analysis is still newly applied in air pollution or aerosol (nano) particle research. We found only 26 publications in Scopus using the keywords: "bibliometric analysis" and "air pollution" on August 8th, 2020, while to nanoparticle on its role as the air pollutant has never been published, even though 33 publications were found when keywords: "bibliometric analysis" and "nanoparticle" applied. Therefore, this study intends to analyze the development of research on exposure evaluation of nano-sized particles in the breathing zone by developing the bibliometric analyses to comprehend what will be needed in future studies.

2. Methodology
We selected Scopus as the database source for searching the study's publications on exposure evaluation of nano or ultrafine particles in the breathing zone. It is an important stage, where the most critical part is to find appropriate keywords that can screen relevant publications of the topic in the research area [15,16]. The combination of these keywords: (aerosol OR airborne) AND ("nanoparticle*" OR “PM0.1” OR “ultrafine particle*”) AND (exposure) AND (“breath* zone” OR “inhalant*” OR “personal”) were applied to search publications on the article title, abstract, and the keywords in the Scopus database on August 10th, 2020. Whole publications were counted, then in-depth bibliometric analyses were performed by limiting only the publications from the journal, which used English as the language [17-22]. For this study, Microsoft Excel and VosViewer 1.6.15 were used to know the main themes in this recent research field. Simultaneously, the most active or productive countries, authors and top-cited documents were also analyzed.
3. Results and discussion

3.1. Growth, sources, and types of collected publications

The searching process in Scopus yielded 769 relevant publications with the first publication that was started in 1985. Nevertheless, publications' growth was still weak and flat between 1985 and 2005, with no document in 1987-1990 and 1993 related to this topic. The slight increase began in 2006, while the highest number of papers per year happened in 2019 (n= 71). Generally, the average number of publications within ~25 documents per year. An increasing number of publications over the years can be determined by using the linear growth curve following the equation \( y = 2.2263x - 4438.1 \) with \( R^2 = 0.765 \). Moreover, the relevant publications also came from several sources and consisted of some document types. The prominent publications sourced from the journal with 711 documents (92.46%) and conference proceeding 4.29 % (n= 33), respectively, while the book 1.95 % (n= 15), book series 1.17 % (n= 9), and one undefined document (not yet categorized by Scopus) followed with just the little percentage.

3.2. Research themes in the literature on exposure evaluation of nano or ultrafine particles

Bibliometric analyses can be used to determine the development of topics in the field of topic. This type of analysis has ever been done to the literature of relation between air pollution and health effects that directly mapped the most frequent terms in title/abstract fields of his collected documents [17]. However, we added one step before that, which mapped the term in the document titles to get a general description of the words used in the documents of exposure evaluation to nano or ultrafine particle literature before mapping the most frequent terms title/abstract fields. Figure 1 shows the mapping of the most frequent terms in the title of documents in the exposure evaluation of nano or ultrafine particle literature with the minimum occurrence was ten. We found 24 terms with five clusters (170 links; 715 total link strength) as the results. Nanoparticle (green; cluster 1), exposure (red; cluster 2), particle (blue; cluster 3), rat (light brown; cluster 4), and evaluation or development (purple; cluster 5) were the most important term for each cluster. The nanoparticle is also the most important term with 191 occurrences (22 links; 242 total link strength) in this field's literature titles.

On the other hand, the terms assessment (cluster 1) and evaluation/and development (cluster 5) have also indicated the recent forms of researches, which are mainly related to the evaluation/measurement/assessment that has grown. In contrast, the terms exposure, exposure assessment, occupational exposure (cluster 1), and inhalation exposure (4) tend to show the researched exposure types. The terms effect, mouse and toxicity (cluster 2), translocation, deposition, Vitro, and lung (3), and rat (4) were signed about the effects which studied.

Figure 1 can be used then for the more sophisticated analysis of the term in the title and abstract on the nano or ultrafine particle exposure evaluation literature. In this analysis, the minimum number of occurrences was 10, and the most relevant terms will be selected by default. Figure 2 shows the result, which found 260 terms and 19,021 links (for 60% results that automatically eliminate irrelevant terms) in three clusters. The most terms were inhalation with 257 links in cluster 2 and area (252 links) in cluster 1, while the term Vitro in cluster 3 was 180 links as the least terms. The developed themes in the literature were determined by listing the terms in each cluster for classified, following:

- Cluster 1 (red), with the terms agglomerate, airborne nanoparticle, area, breathing zone, cascade impactor, chemical analysis, chemical composition, child, collection, condensation particle counter, device or instrument, direct-reading instrument, low-pressure electrical impactor, electron microscopy, elemental carbon, energy dispersive x-ray spectroscopy, engineered nanomaterial, exposure assessment, exposure level, filter, flow rate, geometric standard deviation, mass concentration, measurement, micro-environment, mode, occupational exposure, particle concentration, particle number concentration, particle size distribution, personal disclosure, potential health risk, sample, scanning mobility particle sizer, surface area concentration, worker exposure, and workplace.
Cluster 2 (green), with the terms accumulation, adult, adverse effect, age, alveolar macrophage, animal, association, asthma, blood, brain, bronchoalveolar lavage, cell, cytotoxicity, disease, dose, entry, epidemiologic study, heart, inflammation, inflammatory response, inhalation study, kidney, liver, lung, mice, morbidity, mortality, nose, organ, oxidative stress, pulmonary inflammation, rat, respiratory disease, tissue, toxic or toxicity, uptake, Vitro study, and Vivo. The themes could be
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Cluster 3 (blue) with the terms consumer, consumer product, exposure chamber, exposure system.

From these listing, next, we can determine the research themes. In cluster 1, the terms grew to show whole things related to measurement or assessment of nano or ultrafine particles exposure that entered or inhaled in the breathing zone. Meanwhile, the research theme in cluster 2 was developed to the exposure responses to many subjects (rat, mice, and human) and the effects (such as the terms adult, child, age, alveolar macrophage, asthma, blood, and brain). In contrast, cluster 3 tends to focus on the existence of nanoparticles in consumer products. These themes can be guided to develop researches in this area for further works.

Figure 1. Map of network visualization for the term title on publications related to exposure evaluation of nano or ultrafine particles in the breathing zone.

Figure 2. Network visualization map of terms with title and abstract on evaluation in the breathing zone to nano or ultrafine particle exposure studies.
3.3. Active countries, authorship performances, and top-cited documents

The development of countries that have been involved in this study field was considered. Although the United States is known to be the highest active country in publication with a total of 309 papers (28.88% of the total), followed by Germany and the United Kingdom with 114 (10.65%) and 56 (5.23%), respectively, we found Australia (6th), China (rank 8th), Japan (12th) entered to the top of 15 active countries. Moreover, from fifty-four countries that have contributed to this research, three countries from Southeast Asia, Singapore (15 documents), Thailand (two papers), and Malaysia (one article), respectively, have also engaged in this topic.

The total number of authors who participated in publishing research on exposure evaluation to nano or ultrafine particles in the breathing zone was recorded 2,829 names. This amount means that every document has ~4 authors. Professor Gunter Oberdörster (University of Rochester, United States) was the most productive author with 22 papers (2.19%). Also, the second and third most active authors were Prof. Vincent C. Castranova (West Virginia University, United States) with 20 documents (1.99%) and Prof. Giorgio Buonanno (Università di Cassino e del Lazio Meridionale, Italy) with 17 papers (1.69%), respectively. Figure 3 shows the visualization map of network analysis to the co-citation analysis and cited author with the minimum number of citations of the author set to be 100. The result shows 89 authors included that spread in four clusters, which had 3,886 links and 368,793 total link strength. Moreover, Oberdorster, g. (1,128 citations), Donaldson, k. (701 citations), Kreyling, w. g. (450 citations), Castranova, v. (380 citations), and Morawska, l. (310 citations) are the most co-cited authors in the area of exposure evaluation to nano or ultrafine particle research.

Concerning the top authorship performances, the top-cited documents' analysis also applied with the minimum number of citations of a paper is set to be 360. The top-cited records in the literature of exposure evaluation of nano or ultrafine particles were found in an article from Oberdörster g. (2005) with the title “Nanotoxicology: An emerging discipline evolving from studies of ultrafine particles” (5,313 citations) in the Environmental Health Perspectives journal was on the top highest cited paper, followed by Oberdörster g. (2004) with the title “Translocation of inhaled ultrafine particles to the brain” (1,595 citations) and Warheit d.b. (2004), “Comparative pulmonary toxicity assessment of single-wall carbon nanotubes in rats” (1,269 sources), respectively, as the second and the third ranks.

Figure 3. The co-citation and cited author network visualization map.

4. Conclusion

The comprehensive understanding of the latest popular topics on exposure evaluation studies to inhaled nano or ultrafine particles has succeeded in being developed. The growth and development of studies related to the assessment of nano-sized particle exposure in the breathing zone have been growing since
1985. Still, a significant increase was started just in 2005 or 2006; thus, it can be interesting to evaluate evolution, while this type of study has not developed in this field. The growth of themes, the most active or productive for countries, authors, and cited document analyses, have been described and explained in this study by applying bibliometric analysis. Our findings suggest that the greater depth on appropriate devices for exposure measurements, particularly in nano-sized, which matches with the metrics have to be focused. Three metrics commonly were discussed by researchers, mass concentration, number concentration, and surface area concentration are needed to be chosen or combined when the measurement performed. Through these efforts, the capabilities of analyses can improve for future inhaled nanoparticles exposure assessments.

References
[1] Pedata P, Petrarca C, Garzillo E M and Di Gioacchino M 2016 *Int J of Immun and Pharm* **29**(3) 343
[2] Oberdörster G, Oberdörster E and Oberdörster J 2005 *Env Health Pers* **113**(7) 823
[3] Fireman E, Edelheit R, Stark M and Shai A B 2017 *J. of Nano Res* **19**(2)
[4] Li N, Hao M, Phalen R F, Hinds W C and Nel A E 2003 *Clin Immun* **109**(3) 250
[5] Nel A, Xia T, Mädler L and Li N 2006 *Sci* **311**(5761) 622
[6] Li C, Wu K, and Wu J 2017 *En Sci and Pol Res* **24**(32) 24733
[7] Oberdörster G, Sharp Z, Atudorei V, Elder A, Gelein R, Kreyling W and Cox C 2004 *Inh Tox* **16**(6-7) 437
[8] Warheit D B, Sayes C M, Reed K L and Swain K A 2008 *Pharm and Ther* **120**(1) 35
[9] Abbott L C and Maynard A D 2010 *Risk Anal* **30**(11) 1634
[10] Monn C 2001 *Atm Env* **35**(1) 1
[11] Maynard A D and Aitken R J 2007 Nano **1**(1) 26
[12] Asbach C, Alexander C, Clavaguera S, Dahmann D, Dozol H, Faure B, Fierz M, Fontana L, Iavicoli I, Kaminski H, MacCalman L, Meyer-Plath A, Simonow B, van Tongeren M, Todea A M 2017 *Scie of Tot Env* 603-604 793
[13] Sun J, Zhou Z, Huang J and Li G 2020 *Int J of Env Res and Pub Health* **17**(4)
[14] Jiang M, Qi Y, Liu H and Chen Y 2018 *Nano Res Let* 13
[15] Andreo-Martínez P, Ortiz-Martínez V M, García-Martínez N, López P P, Quesada-Medina J, Cámara M Á, and Oliva J 2020 *Env Tox and Pharm* 77
[16] Su Y, Yu Y and Zhang N 2020 *Sci of the Tot Env* 733
[17] Sweileh W M 2020 *Glob and Health* **16**(1)
[18] Xing Y and Brimblecombe P 2020 *Urb For and Urb Green* 48
[19] Yılmaz M, Grilli M L and Turgut G 2020 *Met* **10**(5)
[20] Dhital S and Rupakheti D 2019 *Env Sci and Pol Res* **26**(13) 13103
[21] Tang Y, Xin H, Yang F and Long X 2018 *J of Nano Res* **20**(4)
[22] Sweileh W M, Al-Jabi S W, Zyoud S H and Sawalha A F 2018 *Multi Res Med* **13**(1)