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Impacts of Mercury Exposure on Human Health, Safety and Environment: Literature Review and Bibliometric Analysis (1995 to 2021)

Suvarna Raju P[1], Otitolaiye VO[1], Mahfud R[1], Al Rawahi M[1]
[1] Department of Health Safety and Environmental Management, International College of Engineering and Management, Seeb, Sultanate of Oman

Abstract

Introduction: Mercury is a highly toxic and persistent contaminant found in food and parts of the environment. Over the years, global research on mercury poison has soared owing to concerns about its effects on human health, occupational safety, and environmental sustainability. Although numerous studies have identified and examined the various types, sources, toxicity, exposure, and impacts of mercury, comprehensive studies on the research landscape and scientific developments on the subject areas are currently lacking. Therefore, this paper shows a bibliometric analysis (BA) and literature review (LR) of the top publications, funders, organisations, and countries working on Mercury research worldwide.
Methods: The research landscape on the subject area was examined by BA from 1995 to 2021, whereas the scientific developments were highlighted through literature review.
Results: Results showed that mercury research has gained global prominence since the discovery of the Minamata disease in 1956. The most prolific mercury researchers, institutions, and funders are from the United States, Japan, Brazil, Canada, and China, whereas the publications on Mercury research doubled over the period. The top source titles for publications on Mercury are Neurotoxicology, Science of the Total Environment, and Environmental Health Perspectives. However, Micheal Aschner (US) and Takashi Yorifuji (Japan) are the most prolific researchers. Co-occurrence analysis revealed that mercury, methyl mercury, fish, toxicity, and Minamata disease are the most cited keywords, which shows the correlation nexus between fish consumption and mercury poisoning.
Conclusion: The LR showed that mercury research is widely investigated due to global concerns about its impact on human health, safety, and the environment.

Key words: Bibliometric Analysis, Human Health, Literature Review, Mercury Exposure, Occupational Safety.

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Corresponding Author
Dr. Suvarna Raju Palathoti PhD,
Assistant Professor,
Department of Health Safety and Environmental Management,
International College of Engineering and Management,
Al Seeb, Muscat,
Sultanate of Oman
E-mail: suvarnarajup2008@gmail.com
ORCID ID: https://orcid.org/0000-0003-1713-6943

INTRODUCTION

Mercury is considered a highly toxic and persistent contaminant found worldwide.[1,2] It is ubiquitous in food, water, air, soil, and other parts of the environment.[3,4] Hg is also found in various materials, equipment, environments, or workplaces, such as the oil and gas industry.[5,6] According to analysts, one of the significant sources of mercury is the burning of contaminated fossil and other solid fuels.[7] Consequently, humans and other living things on the planet encounter various forms of inorganic, organic, and elemental mercury.[8, 9] Typically, the various forms of mercury enter the human body through different routes to the body at different concentrations. [10, 11] The various forms of mercury exert various health consequences that may emerge depending on the exposure time, exposure magnitude, and mercury type.[7]

The inorganic form of mercury enters the human body either through ingestion or skin absorption but not by inhalation due to its non-volatile nature. Regardless, when inorganic mercury enters the body, it is predominantly considerably deposited in the proximal tubule of the kidneys. Although the symptoms of the entry depend on the type of exposure, acute high-dose exposure could lead to severe conditions. For example, it can darken or discolor the oral mucous membrane, which causes burning chest pain, gastrointestinal tract damage, mercurial stomatitis, and damaged kidney functions. Other external symptoms of acute high dose exposure include nail discoloration, mucous membrane corrosion, and corrosive burns. However, chronic exposure to inorganic mercury causes polyuria, proteinuria, haematuria, and anuria. [6,7,8, 10]

The elemental form of mercury enters the human body through inhalation as it is typically present in the form of vapour. When elemental mercury is inhaled, it is quickly absorbed into the lungs at the rate of 80% and then diffused into the blood. The blood carries the elemental mercury into each organ of the body in a period of a few minutes. [8] Typically, elemental mercury stays as vapor during its transportation by the blood but subsequently crosses the blood-brain barrier for onward transmittance to the brain through the nerve cells. Hence, elemental mercury is heavily deposited in both the central nervous system (CNS) and the brain. Furthermore, the exposure of workers to mercury vapor could result in chronic psychological anomalies including but not limited to depression, excitability, insomnia, and memory loss. Moreover, it can result in various physical symptoms like anorexia, fatigue, weight loss, and weakness, whereas in more advanced cases, tremors and renal function damage may occur.[7] Akin to inorganic mercury, elemental mercury also deposits in the kidneys. Once elemental mercury is in the body, the resulting health consequences depend on the type of exposure. Acute exposure to elemental mercury typically results in dermatitis. In addition, acute exposure to high levels of elemental mercury causes hypoxia, which is a fatal reaction that results in severe lung damage or even death. Further symptoms can be observed related to CNS toxicity such as memory loss, paraesthesia, tremors, erethism, hyperexcitability, and delayed reflection.[7, 8]

Several studies have shown that mercury is not only hazardous to human health but can also cause consequences to industrial processes and equipment.[12,13] For instance, the deposition of industrial mercury equipment such as cryogenic vessels and heat exchangers causes corrosion and cracking, which result in severe risks to the operators.[14, 15] Likewise, treatment liquids and sorbents are contaminated by mercury, which could hamper their regeneration, reuse, and disposal. Exposure to mercury is even more hazardous in closed spaces, atmospheres, or environments such as separators, heat exchangers, and tank farms among others.[16, 17] Typically, the enclosed nature of such environments enhances the accumulation and absorption of mercury on the surfaces and dissolutions of equipment and materials such as sludge.[7]

Over the years, research studies on mercury and its exposure, toxicity, and effects on human health, safety and the environment has been carried out in the literature. Furthermore, various techniques for the detection and sampling of mercury levels and concentrations have been proposed and investigated. [18,19,20] For example, techniques for the determination of the accurate levels of mercury in various oil and gas processes are now commonplace. In addition, the use of industrial systems for mercury removal have been installed to detect, separate, extract, filter, vaporize, and eliminate mercury during petrochemical processes. Based on this, the total amount of mercury present in both gaseous and liquid states is quantified, and its potential effects are evaluated to ensure human health, occupational safety, and environmental sustainability.[21, 22] Other strategies include the removal of mercury through sorbents bed that comprise of either granular or pelletized materials (such as metal oxide, zeolite, activated carbon, alumina, and a reactive component bonded to support) for the identification, quantification, and removal of mercury.[23,24,25]

The review of the literature reveals numerous studies on the sources, types, concentrations, toxicity, exposure, and impacts of mercury on human health, occupational safety, and environmental sustainability. Furthermore, an analysis of the literature on the subject area over the last 25 years (1995-2021) in the Scopus database revealed over 800 peer-reviewed publications comprising 150 review papers among others. The large volume of publications on the subject area indicates its social, economic and environmental importance worldwide. However, comprehensive studies on the global research landscape and scientific developments in the subject areas are lacking in the scientific literature. Therefore, this paper shows a bibliometric analysis (BA) and literature review (LR) of the current research landscape, top publications, funders, organizations, and countries working in the area worldwide. The study seeks to provide future researchers, policymakers, and stakeholders with comprehensive information on the area to enhance future research, collaboration, and scientific developments.

METHODS

Bibliometric analysis (BA) is a research methodology pioneered in the 20th century by Eugene Garfield.[23,24,25,26] In principle, it is a mathematical and statistical method used to identify, organize, and analyze critical research works and scientific developments in any given subject area or discipline.[27] In addition, bibliometric analysis can be used to examine the quantity, importance, and structure of a subject area of research.[28] Over the years, bibliometric analysis has been employed to examine and highlight the significant research trends and scientific developments in areas such as knowledge management, microplastics and nano-plastics, human resources, safety culture, Green supply chain management, carbon dioxide utilisation, algae research, municipal solid wastes, medicine.[29,30,31,32,33,34,35,36,37].

In this paper, BA was employed to examine the global research landscape, whereas LR was used to examine the scientific developments on the sources, types, concentrations, toxicity, exposure, and impacts of mercury on human health, occupational safety, and environmental sustainability. The BA was carried out based on the three-step PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) approach of identifying, screening, and analysis of peer-review papers and scientifically indexed literature [37,38,39] The process also involves the exclusion of non-pertinent papers from the search, screening, and analysis [26] Figure 1 shows the methodological design of the identification, screening, and final selection of articles for bibliometric analysis.

In this study, the first step of identification involved the design of the required search string based on the keywords related to the subject area of mercury exposure in the literature. The database selected for this study was Scopus™ which is considered the largest collection of abstracts, citations, scientific journals, books, and conference proceedings in numerous fields ranging from science, social sciences, medicine, arts, and humanities.[40, 41] Next, the search string ((TITLE-ABS-KEY ((“mercury” OR “methylmercury” OR “methyl mercury”) AND poisoning) AND PUBYEAR > 1994 AND PUBYEAR < 2022)) was executed in the Scopus database. The search produced 813 documents comprising articles, reviews, books, letters, editorials, notes, erratum, short surveys, and book chapters. Next, the screening was carried out to eliminate non-traditional peer review types of publications, which limited the results to only articles, reviews, and conference proceedings. The screening search string utilised was TITLE-ABS-KEY ((“mercury” OR “methylmercury” OR “methyl mercury”) AND poisoning) AND PUBYEAR > 1994 AND PUBYEAR < 2022 AND (EXCLUDE (DOCTYPE, “ch”) OR EXCLUDE (DOCTYPE, “le”) OR EXCLUDE (DOCTYPE, “ed”) OR EXCLUDE (DOCTYPE, “no”) OR EXCLUDE (DOCTYPE, “sh”) OR EXCLUDE (DOCTYPE, “er”)). The screening search generated 700 documents comprising only articles, reviews, and conference proceedings for further analysis. Lastly, the 700 selected publications were subsequently analysed to examine the current research landscape, top publications, funders, organisations, and countries working in the area worldwide. VOSViewer was used to identify and examine the network in the research area analyse the co-occurrence, co-citations, and groups within the area.

RESULTS

Publications Trends and Journal Analysis

The analysis of the trends in publications and journals in the subject area is critical to the bibliometric analysis. Figure 2 shows the trend of published documents in mercury research from 1995 to 2021. As observed in figure 2, the number of publications increased from 18 to 40 in the years from 1995 to 2007, whereas a progressively decreasing trend was observed from 2007 to 2021.

The analysis of the types of publications on mercury research during the study period from 1995 to 2021 was also examined. Figures 3(a) and 3(b) shows the distribution of 700 documents (based on the screening process in Fig. 1) and their corresponding subject areas during the period.

The sources of the published documents on the subject area were analysed to examine the most prominent journals or titles preferred by researchers in the field. Figures 4 shows the distribution of publications sources for mercury research from 1995 to 2021 in the Scopus database.

Further analysis was done to show the most prominent journals in Mercury research. Based on the Citescore depicted in Figure 5, the most prominent journal in the area is Environmental Health Perspectives, followed by Science of the Total Environment, Environmental Research, Toxicity, and lastly Neurotoxicology

Figure 6 shows the top researchers in the subject area as deduced from the Scopus database from 1995 to 2021. As observed in Figure 6, the top researchers in the field account for 24.43% or 171 publications from 1995 to 2021.

Geospatial Analysis of Mercury Research

Geospatial analysis of mercury research was examined based on the country, affiliations and funding organization that support researchers in the subject area. This analysis is crucial to measure the research impact of subject areas across the globe. Figures 7-9 present the top 10 countries, research affiliation, and funding organisations of mercury research from 1995 to 2021. Results from Figure 7 reveal that the top countries engaged in mercury research and their publication counts (in brackets) are the United States (258), Japan (146), Brazil (57), Canada (38) and China (33).

Figure 8 shows the top funding organisations that have funded mercury research worldwide during the study period from 1995 to 2021.

Figure 9 shows the top affiliations or organisations for mercury research worldwide. results shows that the top research affiliations or institutions in the subject area are; National Institute for Minamata Disease, University of Rochester School of Medicine and Dentistry (USA), Harvard T.H. Chan School of Public Health (USA), Okayama University (Japan), Kumamoto University (Japan), Universidade Federal do Pará (Brazil), Karolinska Institutet (Sweden), Universidade Federal de Santa Catarina (Brazil), Syddansk Universitet (Sweden), University of Rochester (USA), and Kumamoto University School of Medicine (Japan).

Bibliometric Analysis

The Bibliometric analysis focuses on co-authorship and co-occurrence of the literatures related to mercury research.

Co-authorship analysis

The co-authorship analysis was done using VOSViewer. Figure 10 shows the network visualization of the researchers working in the field of mercury research around the world. The co-author analysis was carried out based on the criteria of a minimum of 5 publications per author, which resulted in the selection of 57 authors that fulfilled the threshold out of a possible 2243 authors.

The analysis of the research organisations and countries that fund and undertake studies in the subject area was also examined in this study. Figures 11 presents the network visualisation of the organisations where researchers are working in the area of mercury research. Figure 11 shows that Harvard University has the most links with other institutions primarily comprising Japanese organisations based on Minamata, Kumamoto, Tohoku and Akita.

Figures 12 presents the network visualisation of the countries where researchers are working in the area of mercury research. From figure 12, it can be seen that the US has the most robust and most widespread links to other countries within the network of mercury research during the study period examined in this study.

Co-occurrence Analysis

Figure 13 shows the map of the co-occurrence of the keywords related to Mercury research deduced from the VOSViewer. This analysis was carried out based on the minimum occurrence of 5 for each keyword, which resulted in the selection of 74 keywords.

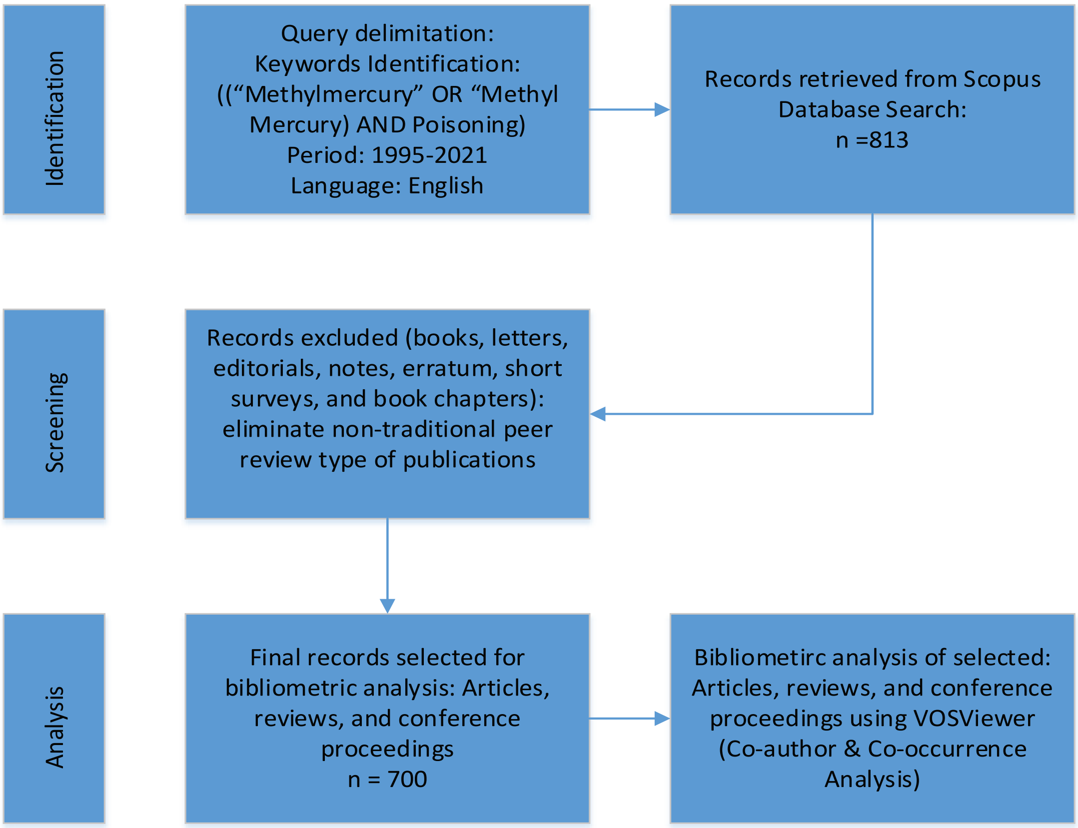

Figure 1: Methodological design of the bibliometric analysis of Mercury research

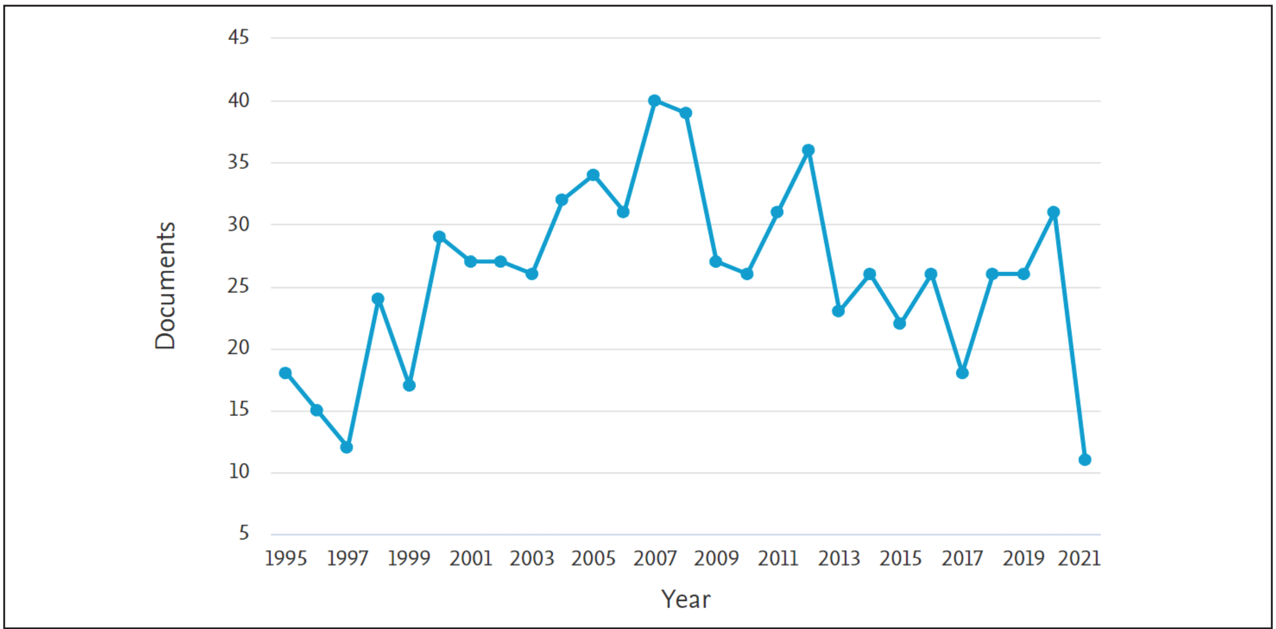

Figure 2: Publications trends for Mercury Research (1995-2021)

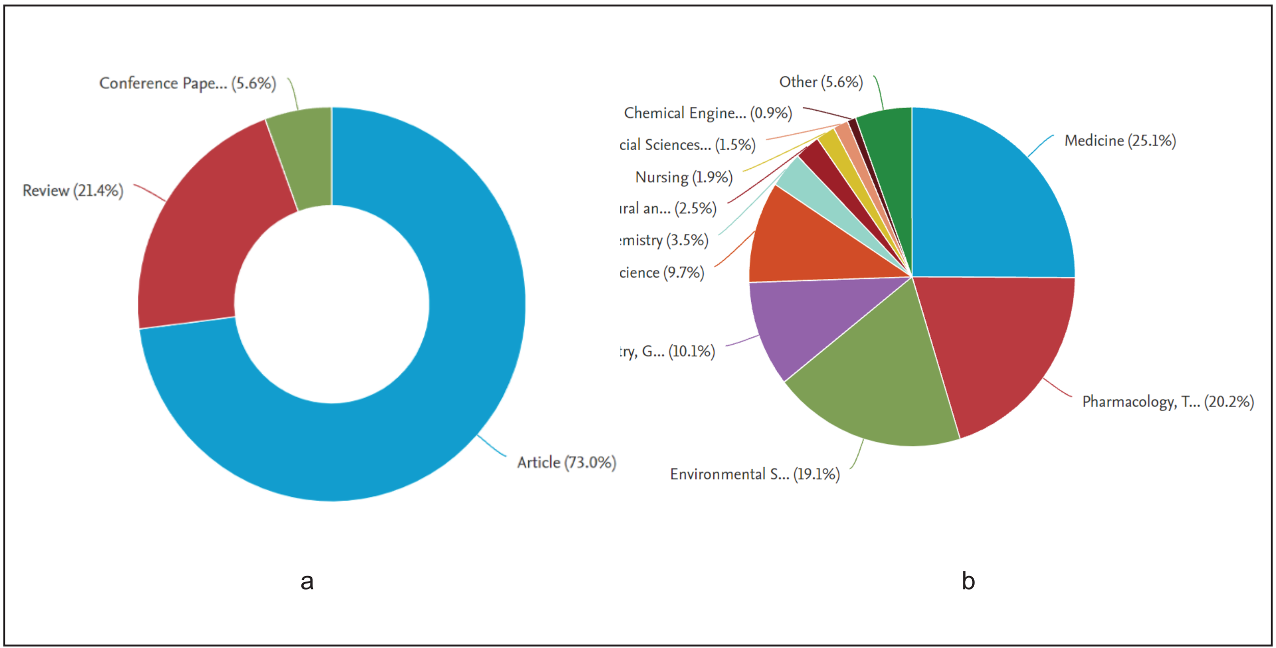

Figure 3: Distribution of publication types and subject area on Mercury publications (1995-2021)

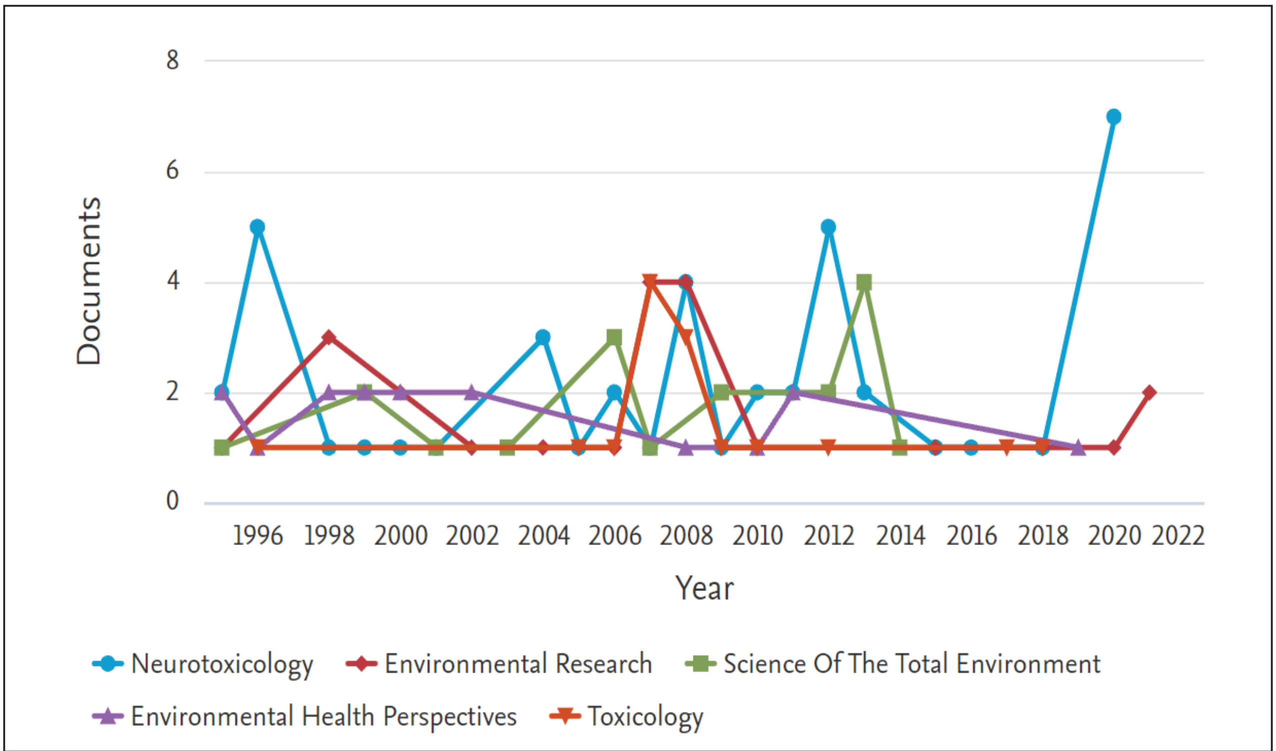

Figure 4: Top five source titles of publications on mercury research (1995-2021)

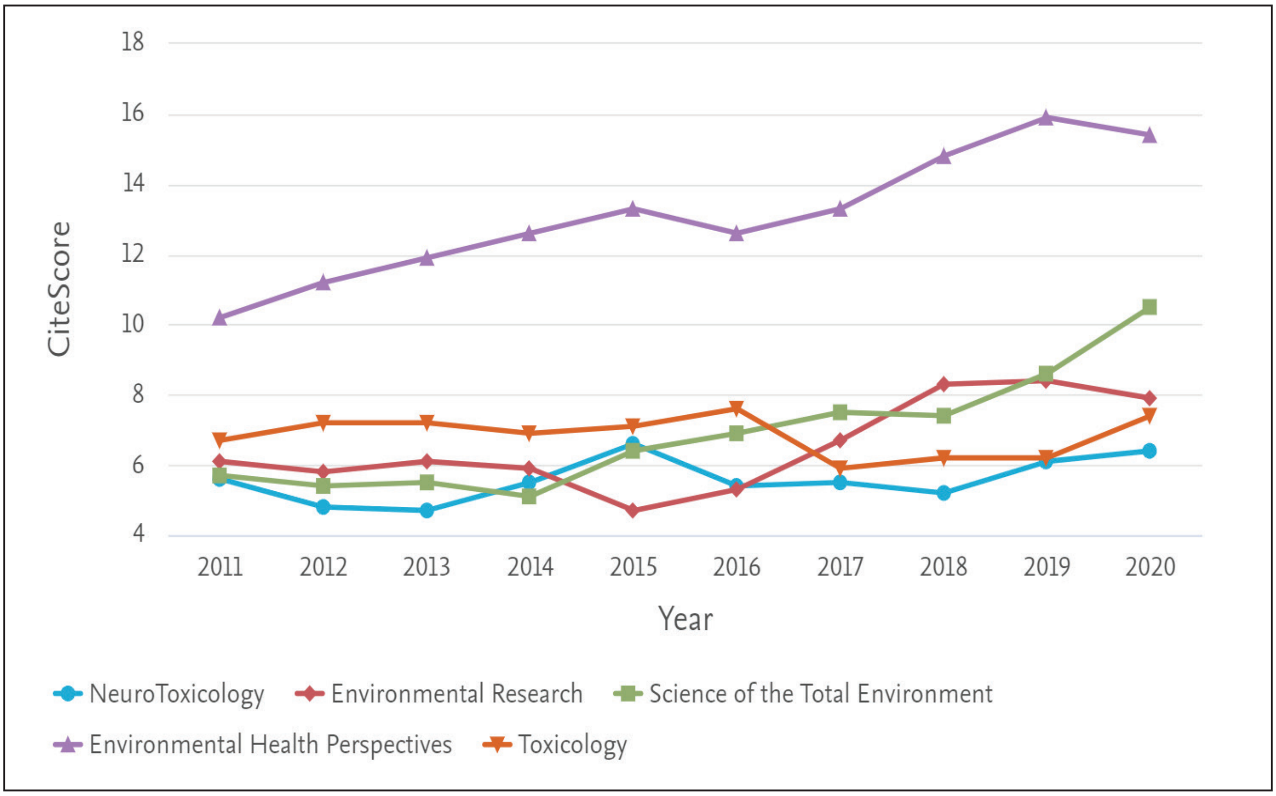

Figure 5: Most prominent journals/source titles in Mercury research (1995-2021)

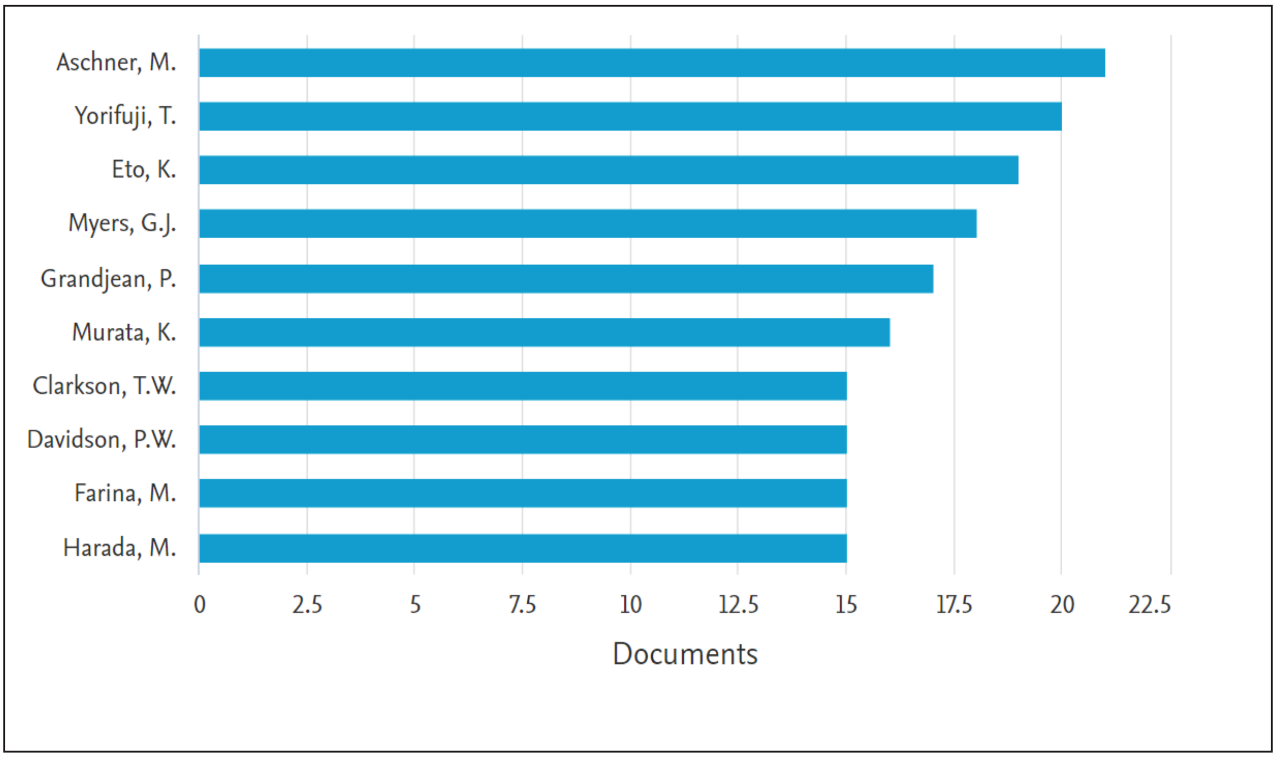

Figure 6: Top 10 researchers in Mercury research (1995-2021)

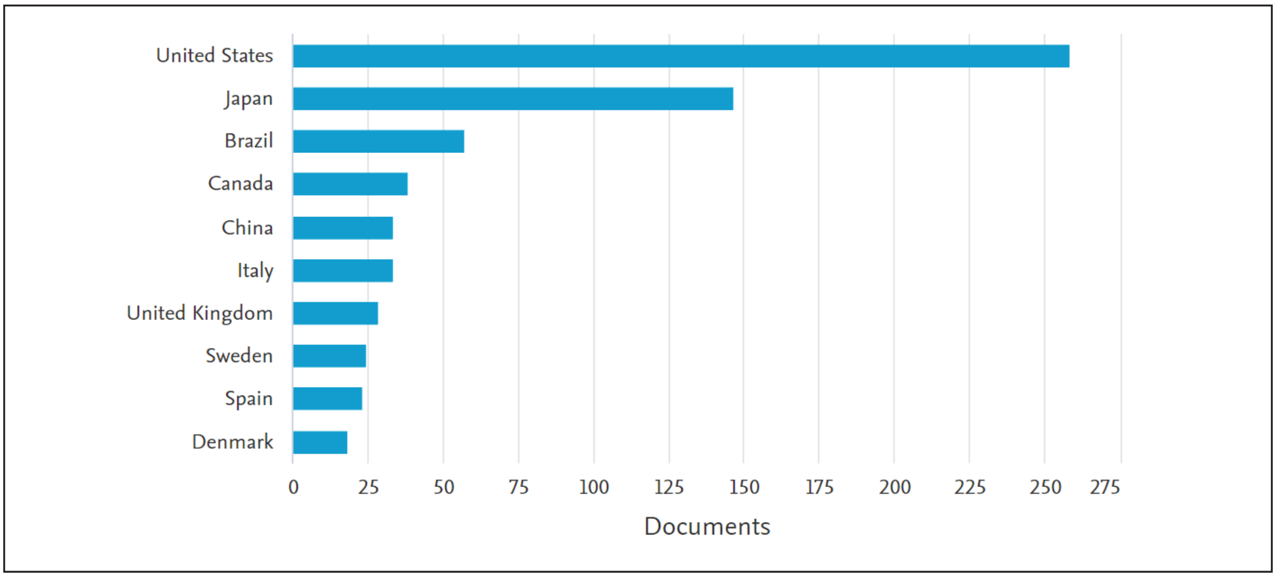

Figure 7: Top 10 countries working on Mercury research from 1995 to 2021

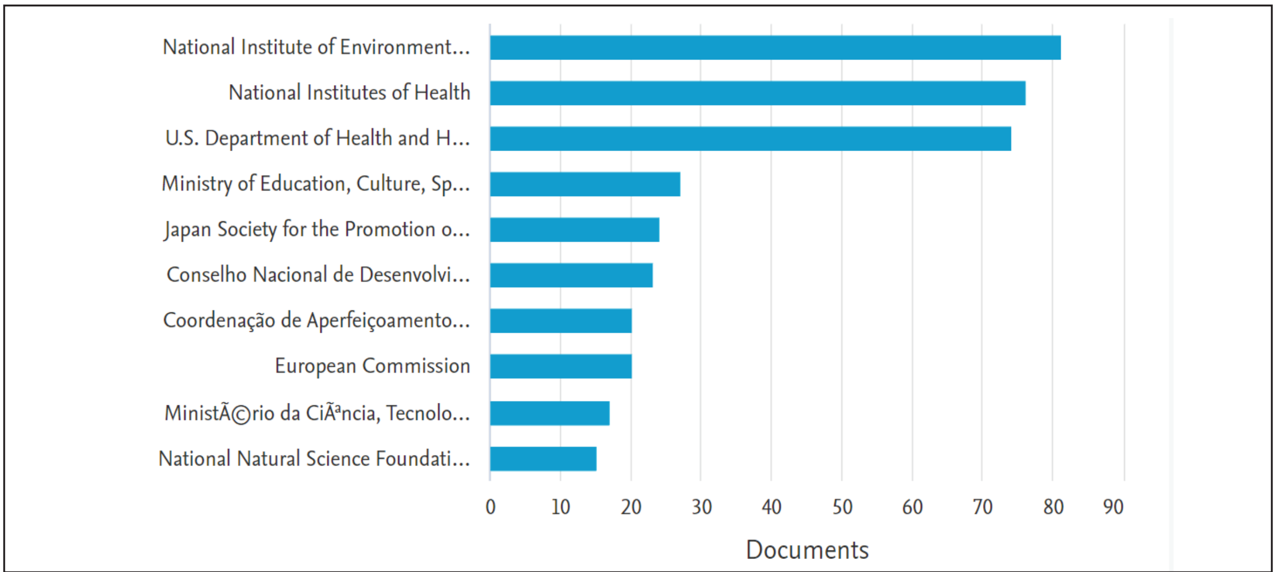

Figure 8: Top 10 funding organisations for Mercury research publications (1995-2021).

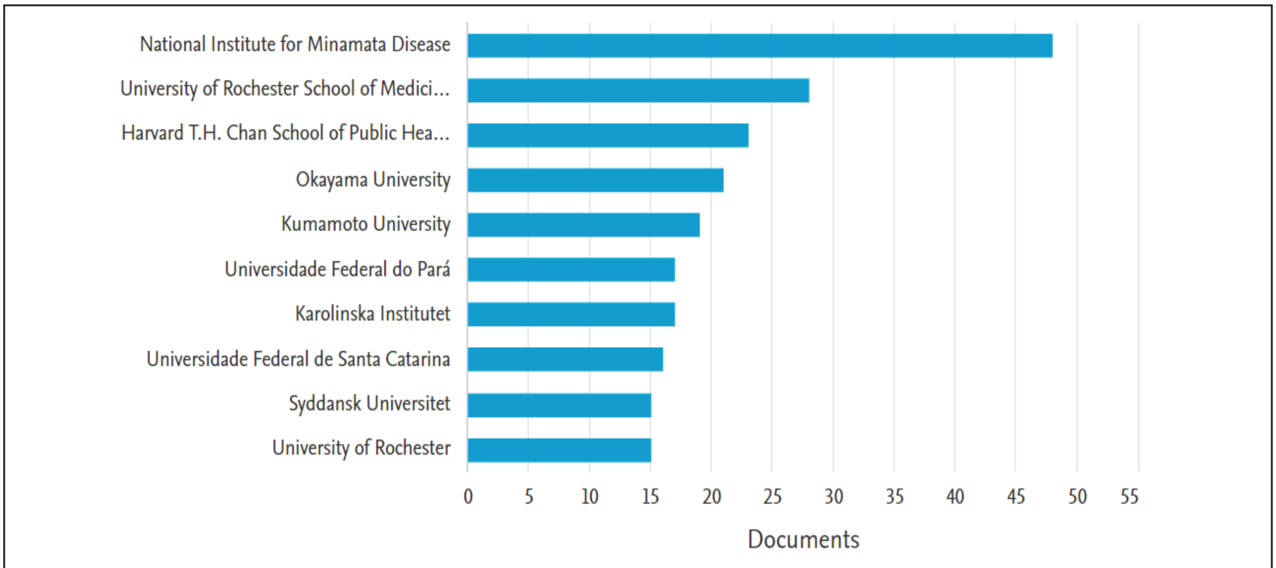

Figure 9: Top 10 research affiliations for Mercury research publications (1995-2021)

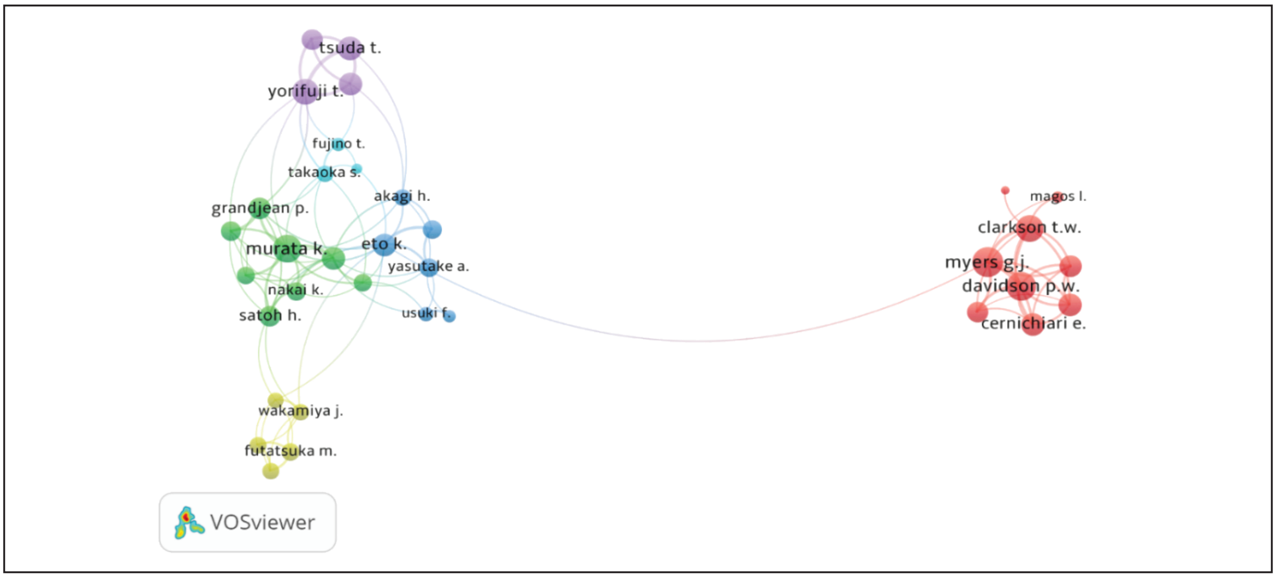

Figure 10: Network visualisation of researchers in Mercury research

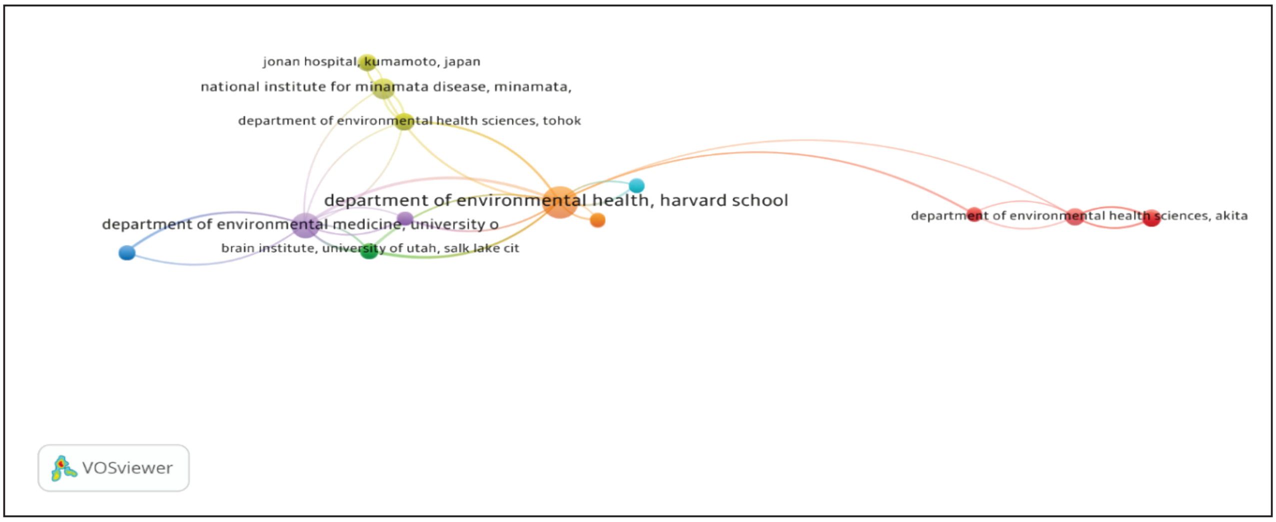

Figure 11: Network visualisation of collaborating research organisations and networks in the area of Mercury research

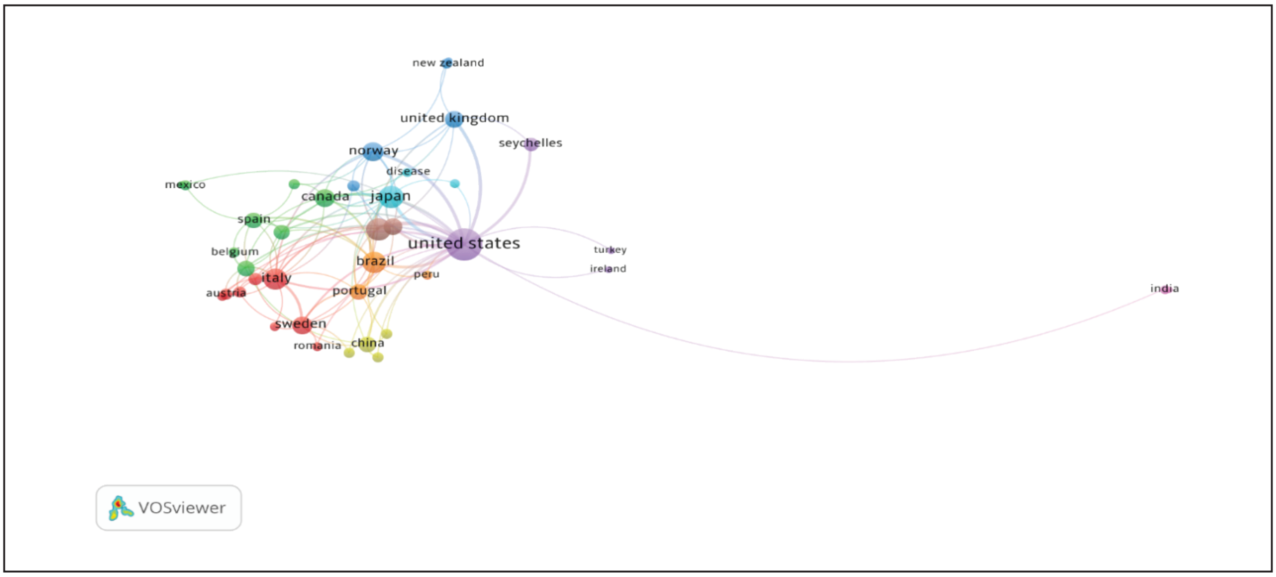

Figure 12: Network visualisation of collaborating countries and nation-based networks in Mercury research

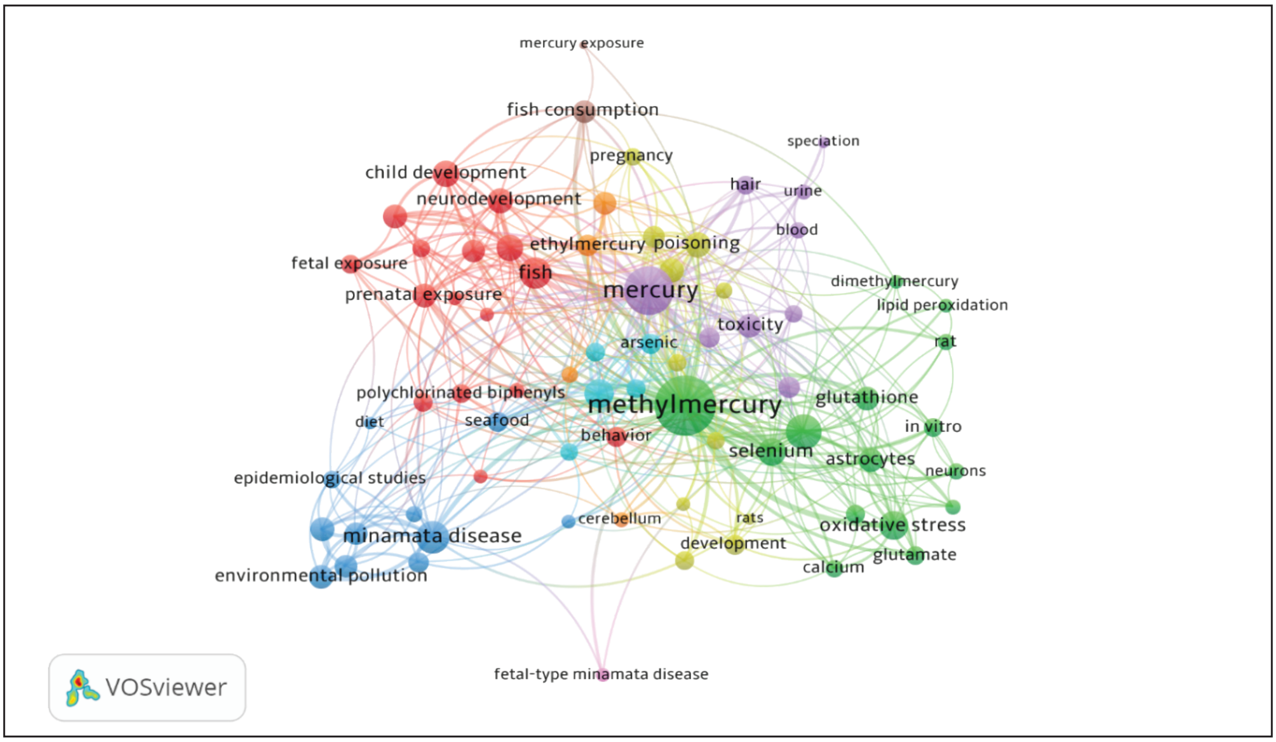

Figure 13: Co-occurrence analysis map of keywords related to Mercury research

Table 1: Top cited authors, publications, source titles, and citations on Mercury research (1995-2021)

Author	Title of Publication	Journal name	Number of Citations	Document Type
Järup[45]	Hazards of heavy metal contamination	British Medical Bulletin	3691	Review
Clarkson and Magos [43]	The toxicology of mercury and its chemical compounds	Critical Reviews in Toxicology	1464	Review
Mozaffarian and Rimm[44]	Fish intake, contaminants, and human health evaluating the risks and the benefits	Journal of the American Medical Association	1456	Review
Harada[46]	Minamata disease: Methylmercury poisoning in Japan caused by environmental pollution	Critical Reviews in Toxicology	1339	Article
Clarkson et al.,[47]	The Toxicology of Mercury - Current Exposures and Clinical Manifestations	New England Journal of Medicine	1331	Review
Zahir et al.,[48]	Low dose mercury toxicity and human health	Environmental Toxicology and Pharmacology	760	Article
Renzoni et al.,[49]	Mercury levels along the food chain and risk for exposed populations	Environmental Research	670	Article
Gilgun-Sherki et al.,[50]	Oxidative stress induced-neurodegenerative diseases: The need for antioxidants that penetrate the blood-brain barrier	Neuropharmacology	632	Review
Goyer [51]	Toxic and essential metal interactions	Annual Review of Nutrition	571	Review
Vahter et al., [52]	Gender differences in the disposition and toxicity of metals	Environmental Research	449	Article

DISCUSSION

As observed in figure 2, the initial increase in publications in mercury research from 1995 to 2007 could be ascribed to the increase in awareness of the health, safety, and environmental impacts of mercury during the period. Another plausible reason could be the global increase in petroleum exploration and exploitation during the same period. The combustion of fossil fuels such as petroleum and coal is one of the largest sources of mercury emissions [7]. According to the study, the increased reporting of the occurrence of mercury could also be due to advanced detection techniques and analytical equipment used in the industry over the years.

As observed in Figure 3(a) the published documents on the subject area include 511 articles, 150 reviews, and 39 conference proceedings, which correspond to 73%, 21.4%, and 5.6%, respectively. Further analysis indicates that > 90% of the published documents on the area of mercury research during the period have been published in peer-review journals, whereas the remainder is typically presented at scientific conferences and meetings by researchers in the area. The subject area analysis revealed that the published documents on mercury research span various fields ranging from medicine to mathematics.

According to Figure 3(b), the top ten subject areas of research and the number of published documents (in brackets) on mercury research are Medicine (290), Pharmacology, Toxicology and Pharmaceutics (233), Environmental Science (221), Biochemistry, Genetics and Molecular Biology (117), Neuroscience (112), Chemistry (40), Agricultural and Biological Sciences (29), Nursing (22), Social Sciences (17), and Chemical Engineering (10). The results indicate that mercury research is a multidisciplinary area due to the diverse fields in which the published documents appear in the literature. According to Lawrence A. Baker, multidisciplinary research is akin to a pot of gold [42], which is due to its ability to reduce bias and present a multiple perspective approach to problem-solving. This approach is critical to studies on potentially hazardous elements such as mercury as its concentration, detection, and exposure require experts from different fields to address the associated issues of health, safety, and the environment.

The findings from figure 4 revealed that the top five source titles for publications and the total number of publications (in brackets) on the subject area during the period from 1995 to 2021 are; Neurotoxicology (44), Environmental Research (22), Science of the Total Environment (18), Environmental Health Perspectives (16), and Toxicology (15). Other top-rated journals in the area include; Neurotoxicology and Teratology (12), Brain Research (11), Toxicological Sciences (11), Toxicology Letters (11), and Ecotoxicology and Environmental Safety (10). The findings from figure 5 indicate that various source titles or journals have published the works of various researchers in the subject area. To examine the impact of these researchers over the years, an analysis was carried out on the top researchers in the area as deduced from the Scopus database from 1995 to 2021.

Figure 6 shows the top 10 researchers based on their publications in the subject area. As observed in Figure 6, the top researcher with 21 publications is Micheal Aschner, who is based at the Albert Einstein College of Medicine of Yeshiva University (New York, United States), who is followed by Takashi Yorifuji (20) from the Graduate School of Medicine, Dentistry and Pharmaceutical Sciences (Okayama, Japan). Others are Komyo Eto (19), Gary J. Myers (18), and Philippe A Grandjean (17) who are based at various institutions in Japan, the United States, and Denmark, respectively.

Top cited publications

The analysis of the top-cited authors and publications is critical to understanding the research landscape and scientific developments in any field of research.[30, 34, 36] Table 1 shows an overview of the top-cited publications in the field of mercury research from 1995 to 2021 based on the Scopus database. The findings reveal that 60% of the number of top-cited publications are reviewed, whereas the remainder is research articles (40). In terms of publication citations, the review articles account for 9145 citations (or 73.97 %), whereas the articles account for 3218 citations or (26.03%) of the total for the top 10 cited publications. The most cited author is Lars Järup who is based at Imperial College (United Kingdom), whose 2003 review publication “Hazards of heavy metal contamination” published in the British Medical Bulletin has amassed 3691 citations since 2003. The second and third most cited publications; “The toxicology of mercury and its chemical compounds” and “Fish intake, contaminants, and human health evaluating the risks and the benefits”, published by and, respectively, are also review papers.[43,44] It is essential to state that only Thomas W. Clarkson and Masazumi Harada are the only top-cited researchers that also appeared among the top authors in the field (Figure 6). The observed disparity may be due to the order of authors in most publications, which predominantly lists the first or corresponding from the list of multiple authors only in bibliographic metrics or journal details.

Geospatial Analysis of Mercury Research

The findings from figure 7 revealed that the top countries engaged in mercury research and their publication counts (in brackets) are the United States (258), Japan (146), Brazil (57), Canada (38) and China (33). As observed in Figure 7, the top 4 nations have developed nation status with the exception of China, which indicates that funding support is a critical factor in the leadership position occupied by these countries. Over the years, funding for research in China has increased significantly, which accounts for the presence of organizations, institutes, and laboratories from the country taking lead positions in research metrics across the globe.

As observed in figure 8, the top funders of mercury research and their publications counts (in brackets) are the National Institute of Environmental Health Sciences (81), National Institutes of Health (76), U.S. Department of Health and Human Services (74), Ministry of Education, Culture, Sports, Science and Technology (27) and the Japan Society for the Promotion of Science (24). Further analysis revealed that the top five funders for research in the subject area are based in the US and Japan. However, other major funding institutions include; Conselho Nacional de Desenvolvimento Científico e Tecnológico (Brazil), European Commission, Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (Brazil), Ministario da Ciancia, Tecnologia e Inovasiao (Colombia), and National Natural Science Foundation of China (China).

Figure 9 shows the top affiliations or organizations for mercury research worldwide. The findings from figure 9 confirm that the most prominent organizations in mercury research are primarily based in the US, Japan, Brazil, and Sweden. In addition, the other organizations were found to also contribute significantly to research, funding, and collaborations within the subject area. Therefore, the co-authorship and co-occurrence analysis was carried out to examine the extent of networks and collaboration maps for the top researchers, organizations, and countries in the subject area of mercury research over the years from 1995 to 2021. To this effect, VOSViewer was employed.

The co-authorship analysis in figure 10 shows an overview of the various network of scientists and researchers working or collaborating with their peers in a given subject area. Figure 10 shows the network visualization of the researchers working in the field of mercury research around the world. The network visualization revealed 6 clusters (based on colors) comprising a total of 35 items (authors), which excludes researchers with no connections or collaborations with others in the network. Based on total link strength, it can be inferred that 5 clusters (with the exception of the red cluster) have had close collaboration or research ties with others over the years examined in this study. Further analysis revealed that the red cluster mainly comprises researchers in the United States who have ties with only the blue cluster. The findings indicate that although active, the researchers in the red cluster have limited research times or collaboration in the network of the subject area. However, the authors within the other 5 clusters comprising most researchers in Japan have strong links with each other as depicted in Figure 10. This could be attributed to the discovery of the so-called Minamata disease caused by mercury poisoning discovered between the 1950s and 1960s in the city of Minamata, Japan. The direct discharge of mercury by a chemical plant in the city resulted in the poisoning of locals which gave rise to the disease and widescale research into the occurrence, symptoms, and effects of mercury poisoning. Years later, research into the disease has soared in Japan, which accounts for the high numbers of researchers from Japan working in the subject area.

Based on the analysis in VOSViewer, from figure 11, the network of research organisations working and most substantial collaboration are primarily between Japan and US organisations, which confirms earlier findings of the location of the most prominent researchers in the subject area. As observed in Figure 11, Harvard University has the most links with other institutions primarily comprising Japanese organisations based on Minamata, Kumamoto, Tohoku and Akita. Figure 12 reveals the existence of 9 clusters (based on colours) with the firm and most diverse links observed for the United States, Japan, Norway, Brazil, UK, Italy, and Sweden. This observation indicates that mercury research is widespread among these nations based on the strength of the links.

Co-occurrence Analysis

The co-occurrence of the related keywords on mercury research was carried out in this study. Co-occurrence analysis gives an indication of the structure and focus of the subject area.[53, 54] The nodes indicate the frequency with which each keyword appears in search of related keywords.

The results from figure 13 revealed 74 keywords and 9 clusters (based on color). As observed, the most significant nodes were mercury, methyl mercury, fish, Minamata disease, and environmental pollution. The largest node (green cluster) reveals the impacts of mercury on the distribution of elements, compounds, and related physiological reactions in the body of living organisms. The second-largest node (purple) shows the prevalence, toxicity, and tissues where mercury is detected or transported in living organisms. The red node also depicts the sources and toxic impacts of mercury exposure, notably its widely-reported effects on the child, prenatal, or neurodevelopment of organisms through seafood consumption. Overall, the keyword co-occurrence analysis revealed that mercury research is multidisciplinary and multidimensional with effects on human health, safety, and the environment.

Literature Review

Following the discovery of Minamata disease in the 1950s in Minamata (Kyushu Island, Japan research interest into the occurrence, sources, and effects of mercury has soared significantly.[55,56] Over the years, research into mercury poisoning and related illnesses has expanded beyond the shores of the city of Minamata in Japan, particularly with the discovery of mercury in various processes, industries, and environments. Due to the extensive studies currently existing in the Scopus database, the review of literature on mercury will be limited to the significant cited studies from 1995 to 2021 retrieved for bibliometric analysis in this paper.

One of the pioneer studies on mercury poisoning was published by Harada.[46] The author investigated the role the environment plays in the proliferation of Minamata disease (or Methylmercury poisoning) in Japan. The author revealed that the disease was first discovered in patients who consumed fish and shellfish contaminated with high levels of methyl mercury ranging from 5.61 to 35.7 ppm discharged into water by a chemical factor based on the Island of Kyushu in Japan. As a result, patients suffering from the disease exhibited symptoms such as ataxia, dysarthria, visual field constriction, auditory disorders, and sensory disturbances, whereas fetuses manifested extensive lesions on the brain.[46] Other studies such as presented evidence of early symptoms of dysfunction of the central nervous system caused by low levels of methyl mercury in people of Amazonia.[57] Likewise, Renzoni et al. [49] demonstrated the link between food consumption and mercury poisoning with its ancillary risks to human health, safety, and the environment. The authors showed that the Mediterranean basin contains a high anomalous prevalence of natural mercury, which creates a high mercury body burden for marine animals in the region. Hence, the consumption of mercury contaminated seafood poses severe risks to the health and safety of the people in the region. Further analysis of the blood and hair of fishermen and pregnant women in the region showed high levels of methyl mercury along with symptoms of diseases reported for Minamata disease.

Zahir et al. reported on the toxicological effects of low doses of mercury on human health and safety.[48] The study revealed that the pollution of water sources by mercury results in the contamination of water, marine life, and other surrounding habitats. Over time, the various forms of mercury, such as inorganic mercury, undergo a microbiological transformation into its lipophilic organic form typically called methyl mercury, which is subsequently biomagnified in the food chain. When contaminated foods are consumed, the infected humans exhibit acute to chronic symptoms of mercury poisoning depending on the length of time of exposure. According to a study, mercury poisoning has been ascribed to numerous cardiac, genetic, motor, immunological, nephrological, neurological, and reproductive disorders. Evidence also suggests there is a link between mercury poisoning and degenerative illnesses such as Parkinson's, Alzheimer's, Lupus, Autism, and Amyotrophic lateral sclerosis.

Gilgun-Sherki et al. highlighted the effects of chemical species such as mercury on oxidative stress and the onslaught of induced-neurodegenerative diseases.[50] showed the effect of gender differences on the nature and toxicity of toxic heavy metal contaminants such as mercury.[52] The study revealed that males are more prone to the neurotoxic impacts of methyl mercury than females. Holmes et al. revealed that acute and prolonged exposure to occupational and environmental sources of mercury and organic mercury compounds cause damage to the central nervous system, thyroid gland, and organs such as kidneys in the human body.[58] In another study by, the effects of mercury were the lungs was the most profound effect on human health. The authors also reported that the distribution of mercury in human tissues and organs is a function of type of compound and duration of exposure.[59]

However, the most common entry point for absorption, as well as acute and chronic mercury poisoning in the human body, is the respiratory system. Hence, the authors reported that the most critical organs affected by mercury poisoning are the lungs, which reportedly cause respiratory illnesses such as bronchiolitis, pneumonia, and bronchitis among others reported in the literature.[59]. Other notable studies in the literature have also reviewed and highlighted the toxicological effects, pollutant prevalence, and environmental impacts of toxic heavy metal elements such as mercury on human health, occupational safety, and environmental sustainability.[43, 45, 47, 60, 61]

CONCLUSIONS

The paper examined the research landscape and scientific developments on Mercury exposure and its effects on human health, safety, and the environment. Bibliometric analysis was used to examine the research landscape on mercury research over a 25-year period from 1995 to 2021, whereas the literature review of the significant publications was carried out the highlight the scientific developments in the subject area over the study period. The findings revealed that the subject had gained prominence from the first discovery of mercury poisoning in 1956 on the Japanese island of Kyushu to date. The number of published articles on the subject area doubled over the period under consideration which may either be due to increasing public concerns about the growing emissions, toxicity and occurrence of mercury and its related compounds in the environment. The results also showed that the most active mercury researchers, institutions, and funding organizations are based in the United States, Japan, Brazil, Canada, and China. Bibliometric analysis showed that although numerous research clusters exist for mercury research, the most collaborative researchers and organizations are based in Japan, whereas the most prolific are based in the United States. The co-occurrence analysis revealed that the most widely cited author keywords are mercury, methyl mercury, fish, toxicity, and Minamata disease. This indicates the correlation between the consumption of seafood such as fish and the occurrence, toxicity, and impacts of mercury on human health, safety, and the environment. The review of the literature showed mercury research is a widely investigated area of research, which may be primarily due to the growing concerns about emissions from the burning of mercury-contaminated fossil fuels and its impact on the health and safety of humans, fetus, or child development as well as other living organisms in the environment.

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