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Ocean Pollutants and Human Health: A Scientometric Perspective

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Abstract

Oceans occupy more than 70% surface of the Earth, and are an important part of sustaining ecological balance and human life. Unfortunately, growing human interventions are transforming the ocean into a collection basin of various types of contaminants that threaten not only marine heath but human health as well. The purpose of this study is to provide a scientometric review of global research about ocean contaminants and human health over the last twenty years (2004 - 2024), and to assess the relevant research coming from India. A search of the Web of Science Core Collection (WoSCC) resulted in a total of 20,688 global publications (articles, reviews, and conference papers) related to the category of ocean contaminants and human health. Only 1,624 publications were from India, which were analysed using VOSviewer and MS-Excel. The results of keyword mapping revealed that “heavy metals” keyword was most often used by authors, in addition to others such as bioremediation, phytoremediation, adsorption, and toxicity risk assessment. Studies frequently looked at contaminants such as arsenic, cadmium, and lead, as emphasis was placed on bioaccumulation and ecological problems. Country collaboration mapping indicated that India holds a strong position globally, with significant collaborative studies with the USA, Germany, and Australia, as well as with researchers and institutions from India including IITs, BHU and CSIR. The research themes align strongly with Sustainable Development Goals. Indian funding agencies including UGC, DST, and CSIR was a first choice for funding from Indian authors in this research domain.

Keywords: Heavy metals, Human health, Organic pollutants, Toxicity, Water

Introduction

The oceans are an essential life-sustaining system that regulates the climate of the planet, produces oxygen, and provides the primary source of protein for over three billion people (1). However, this vast system is increasingly shifting from its capacity to sustain life to a defined medium for global public health threats; it is now becoming the ultimate sink (detector) for a mixture of increasingly complex and anthropogenic pollutants (2). The continuous influx of pollutants into our oceans from multiple pathways — including plastics, agriculture runoff, human waste, industrial chemicals, pharmaceuticals, and mining wastes — is silently creating a widespread and multifaceted health crisis. Pathways linking pollution in the ocean to human health are increasingly becoming well documented, particularly through consumption of contaminated seafood, inhalation of saltwater aerosol, or through direct skin contact (3)(4).

There are many diverse chemicals and substances that threaten marine ecosystems and indirectly threaten human health.The threat of microplastics (MPs) and nanoplastics (NPs)

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is a growing concern at this time.MPs and NPs derive from the breakdown of larger plastic debris and directly from products and textiles. These particles have been found at various levels of the marine food web (5). There is a threat of physical presence leading to gut blockages and inflammatory responses as well as oxidative stress on cells (6). Also, an even greater threat is that MPs act as vectors for contaminants which become attached to the MPs in the water column, such as heavy metals, persistent organic pollutants (POPs) and potentially pathogenic bacteria including Vibrio spp., which together, leads to greater exposure to humans once the contaminated organisms are consumed (7)(8).

At the same time, old chemical contaminants still entail considerable and documented risks. for example Methylmercury, a toxicant produced from industrial mercury emissions and bioaccumulating in predatory fish, such as tuna and swordfish, remains a global concern. Epidemiological studies have established its long-standing effects on the developing nervous system, and even at low doses, it can lead to cognitive impairments, memory problems, and motor impairments in children (9)(10). Persistent organic pollutants (POPs), includes industrial chemicals, polychlorinated biphenyls (PCBs), and pesticides. Many POPs are endocrine-disrupting chemicals (EDCs)- substances that can interfere with hormone systems, such as estrogen and thyroid hormone, by mimicking or obstructing natural hormones (11). EDC exposures have been linked to health problems ranging from reproductive problems, infertility, neuro-developmental deficits in children, and increased risk of hormone-sensitive cancers, such as breast and prostate cancer (11)(12). Assessing the potential impacts of ocean pollutants on human health is the cause of concern. Humans are not generally exposed to a singular pollutant; however, they are exposed to time-varying mixtures of plastics, chemicals, and toxins that could have an overall toxicological impact that is additive, synergistic, or antagonistic (13).

To counter this complex issue, the global scientific community has established a significant, growing, and interdisciplinary body of literature over the past two decades. This literature incorporates various fields of study, including marine biology, environmental chemistry, toxicology, epidemiology, ecotoxicology, and public health.

This is when the utility of scientometrics comes into play. Scientometrics is the quantitative study of scientific communication and literature. Scientometrics offers tools for both analytical computations and visualization to map the structure and dynamics of scientific fields (14). Further, it is possible to use techniques such as co-citation analyses, bibliographic coupling, co-occurrence of keywords analyses, and burst detection in scientometrics to objectively identify the knowledge bases of a field, map the development of research thematic progression over time, visualise collaborative international and institutional networks, and detect emerging frontiers or potentially gaps in less-explored knowledge (14)(15). This methodology has been successfully applied to map research landscapes in related areas, including microplastics in general (16)(17), as well as broader environmental health areas. However, there has not been a comprehensive scientometric analysis explicitly focused on ocean pollutants and human health, specifically taking into consideration the entire suite of contaminants and potential pathways through which they could be transmitted especially in Indian context.The existence of this gap provides an opportunity to understand how the field has changed over the years. This study aims to address this with a comprehensive, scientometric analysis of the global peer-reviewed literature on ocean pollution and human health over the past 20 decades (2004-2024) focussing India. The aims of the study are:To determine the path of the field's growth, primary contributing countries and journals of significance.

2. To map active research fronts and active research area through co-occurrence analysis of keywords.

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3. To analyse the networks of international collaboration and institutional collaboration to indicate knowledge exchange and future collaboration potential.

Materials and Methods

Methodology

A scientometric methodology was employed to examine the research trajectories of ocean pollutants, heavy metals, and their implications on human health within the Indian context. The Web of Science (WoS) Core Collection database was used as a data source of information as it provides comprehensive coverage of peer-reviewed research across disciplines.

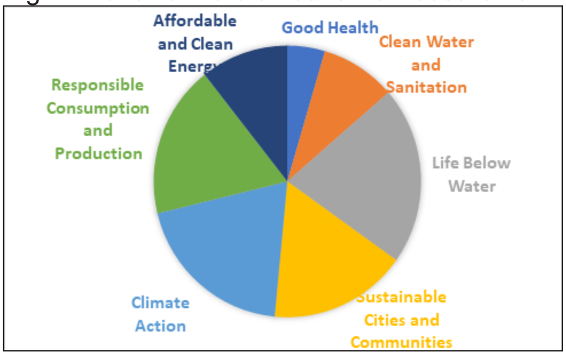
The search was performed using the keywords "ocean pollutants*," "human health*," and "heavy metals*." Total 20,688 documents were found in WoS and in order to focus the search to India, we applied the data restriction with two qualifiers: (i) country restriction as India; and (ii) publication years from 2004 to 2024. To standardize the quality and depth of the analysis, we restricted our search only to research articles and review articles. After applying the restriction, the resultant data yielded 1,624 documents. The selected documents were downloaded as plain text from the WoS database that included all record data, as well as cited references for each document. Data were analysed with Excel and VOSviewer, where Excel produced the yearly publication produced, citation counts, and institutional output. VOSviewer was applied to produce bibliometric mappings for co-authorship networks, keyword co-occurrence, and citation networks to represent an intellectual structure and research hotspots within the ocean pollutants, heavy metals, and human health context.

Analysis and interpretation

Alignment with SDG

Most of the research published of total publications (40.6%) supports SDG 3 (Good Health and Well-being). Moreover, SDG 6 (Clean Water and Sanitation) received 21.7% of publications, which shows a focus on topics related to quality of water and sanitation. Another area of interest is SDG 14 (Life Below Water) with 12.3% publications. This demonstrated an increase in research interest and education focused on marine and aquatic ecosystems. Some publications also supported SDG 11 (Sustainable Cities and Communities)with 9.2% publications (figure 1).

Fig.1: It shows the distribution of research arti-



cles that support the Sustainable Development Goals (SDGs)

Funding Agencies

The University Grants Commission (UGC) is the primary funding agency, with a count of 138 funded publications, followed by the Department of Science and Technology (DST) with 114 funded publications. The Council of Scientific and Industrial Research (CSIR) with 71 funded publications, while the National Research Foundation of Korea (21), and the Department of Biotechnology (DBT), with 13 funded publications, are also recognized as significant contributors. The Science and Engineering Research Board (SERB), the Indian Council of Agricultural Research (ICAR), the Indian Council of Medical Research (ICMR), and the Ministry of Earth Sciences (MoES) also are notable contributors, but, with a much lower count, they typically range between 9 and 14. The figure 2 indicates that the national funding agencies, including the UGC, DST, and CSIR, are a fundamental sector in the research ecosystem in India.

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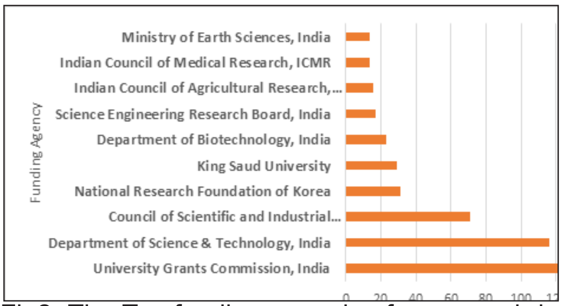
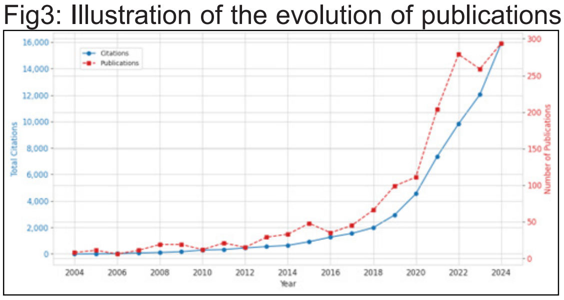


Fig2: The Top funding agencies for research in India in the research domain

Publication and citations

The figure 3 indicates that India's research output and impact have been increasing steadily. Both publications and citations remained relatively low and stable until around 2013, after which a marked upward trend was observed. There is a notable increase after 2018, and the upward trend becomes much steeper after that year, suggesting that both research productivity and research visibility were on the rise. By 2023-2024, citations achieved their highest levels, suggesting that research activity has increased more recently, along with improvements in quality and improved international visibility of Indian scientific work.

Fig3: Illustration of the evolution of publications

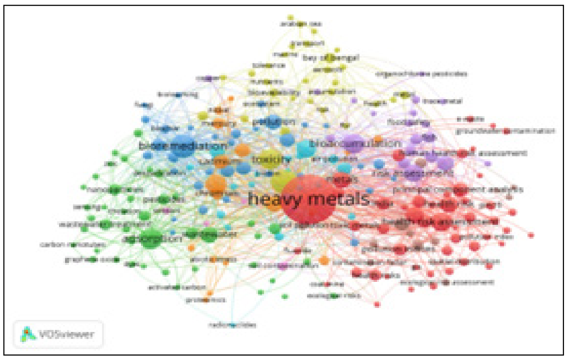


and citations over time (2004-2024)

Keywords co-occurrence

The analysis of keyword co-occurrence mapping revealed that the most prominent theme, "*heavy metals*," appeared 388 times, resulting in the highest total link strength of 734. This further suggests that heavy metals serve as the nucleus of the research and are surrounded by other keywords. A fundamental cluster of studies were oriented towards remediation-based approaches. Keywords that demonstrated a strong research focus on hazard mitigation methodologies includes*bioremediation* (84 times), *phytoremediation* (56 times), and *adsorption* (68 times). Another identifiable cluster focuses on toxicity and health risk assessment. Examining the keywords *toxicity* (65 times), *human health* (49), *health risk assessment* (58), *risk assessment* (51), *hazard index* (36), and *hazard quotient* (28), it shows that researchers concerning heavy metals are equally concerned about the potential impact of heavy metals on human health. Based on the terms groundwater (42), wastewater (39), and bioaccumulation (60), the transport and bioaccumulation of heavy metals in environmental systems have been studied to some degree (figure 4).

Fig 4: Keyword co-occurrence mapping using

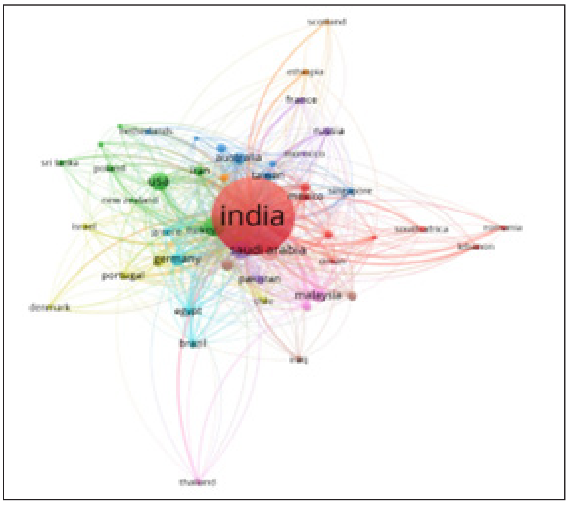


all keywords used by authors of the documents analysed

Countries collaboration mapping

The mapping (figure 5) represents a star pattern with India in the middle, indicating that its research network is global and diverse. Diversity encompasses economically developed countries in North America and Europe, larger economies in East Asia and Australia, as well as developing partners in the Middle East, Africa, and Southeast Asia. The thickness of the lines and the size of the nodes highlighted that collaborations with the USA and other major research economies, such as Germany and Australia, are likely the most consistent and significant in terms of co-authored outputs. The large number of countries connected to India indicates the active capacity of India's international research collaboration with various prominent players.

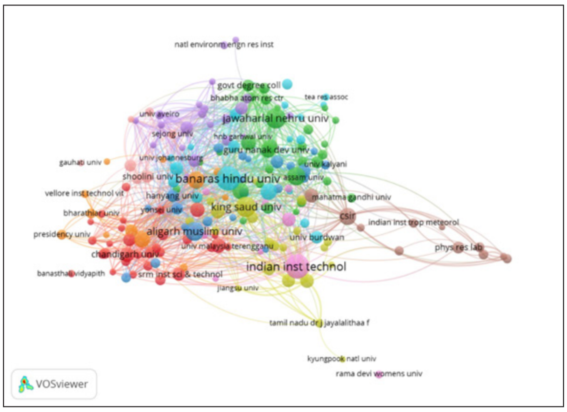
Fig 5: Mapping of India's International collaboration with most active countries in the field



Collaboration between organisations

The collaboration map (figure 6) shows a highly interconnected research universe. It displays the structure of the research istitutions, characterized as a few large hubs within the Indian Institute of Technology (IIT) System and Banaras Hindu University (BHU), which are the most prolific and central academic collaborators from India engaging in this area of research. Although the IIT and BHU are central at the center of the collaborative structure, the Council of Scientific and Industrial Research (CSIR) serves as another important anchor point to support change in the network. The IIT System, BHU, and CSIR connect multiple research communities from across the country.

Fig 6: Illustration of the collaboration of India's prominent institution in the field of ocean pollutants



The large cluster represents a strong and interconnected academic community that includes Jawaharlal Nehru University and universities from central India, a strong representation of collaboration across a broad academic timeline. Another cluster supports national scientific laboratories e.g., CSIR and the Indian Institute of Tropical Meteorology. This implies a different collaborative pathway, as this community of research likely will be funded through public agency funding, indicating a topical research focus in environmental science. Another important cluster is associated with major technical and private institutions, such as Aligarh Muslim University and SRM Institute of Science and Technology, suggesting some new integration into the national research infrastructure contributing to the science ecosystem in India.

Discussion

The scientometric review indicates that there has been marked growth in the area of research on ocean pollution and human health over the last two decades, with the increased trajectory in research output accelerating after 2014, reinforcing the growing recognition of ocean health as a component of public health and overall sustainability.

The prolific approach to heavy metals as the central area of research goes well with the India's ongoing problems with industrial effluents, mining effluents, and agricultural runoff, and in fact, these are the major contributors of heavy metal contaminated waterbodies. Clusters of bioremediation, phytoremediation,

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and adsorption, suggest that remediation and mitigation of hazardous chemicals remains a priority area of research, supporting national management strategies.

The collaborative mapping demonstrated a developing and solid research ecosystem. At a national level, leading institutions, such as Indian Institutes of Technology (IITs), Banaras Hindu University (BHU) and Council of Scientific and Industrial Research (CSIR) serve as key arenas in the collaborative network. This gives evidence of a promising trend towards interdisciplinary collaborations between environmental sciences, toxicology and public health. At an international level, India's collaborations and partnerships with the United States, Germany and Australia indicates an increase in its involvement at the global level on marine pollution and health. Collaborative efforts could also boost methodological capacity and data sharing which are essential for tackling transboundary pollution global challenges.

Although growth has been consistent, some gaps persist. Research continues to focus mainly on traditional pollutants, such as heavy metals, and has not yet been directed toward emerging contaminants, including pharmaceuticals, nanoplastics, and endocrine-disrupting chemicals. There have also been calls for more research on socio-economic health outcomes, which could provide a more sophisticated understanding of the human vulnerability context.

Conclusion

India's lead role in domestic and international research partnerships is centered around its top academic and scientific institutions, particularly the IITs, BHU, and CSIR, as well as considerable life science capacity in various university departments. Although collaboration with tier 2 and tier 3 institutions in India may help to know more about the new contaminants, the combination effects of contaminants on health, and the socio-economic and health impacts of contaminants, this indicates a gap for future research directions as well as less number of scientometric studies highlighting this area.

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