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EVALUATION OF HIGHLY CITED PAPERS IN ENVIRONMENTAL SCIENCES: A CASE STUDY OF INDIAN CENTRAL UNIVERSITIES

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Abstract

Objective-The paper analyzed the highly cited papers (HCPs) published by the ten major Indian Central Universities in the field of Environmental Sciences as reflected in Scopus.

Methods-In Scopus, 'affiliation search' was carried out using the keyword 'University, India', which retrieved 986 affiliations. The total publications of the top ten central universities were 12,052, out of which 9723 were journal articles. The next limit applied was TC2021 ≥100 (TC2021 was the total citations since publication until 2021) retrieved 306 highly cited journal articles.

Major Findings-These 306 HCPs were scattered over 117 journals, contributed by 1825 individual authors employed in 10 central universities, 550 international and 124 national institutions. Bioresource Technology, was the most productive journal, M. Agrawal, BHU, was the most prolific author. The mean author per paper was 5.96, average paper per author 0.168 and 7.2 co-author per paper. The central universities produced 90 HCPs in collaboration with 550 international institutes from 75 countries and 65 collaborative papers with 124 national institutes. The USA, UK, China and Saudi Arabia were the leading collaborating countries. King Saud University, Mississippi State University and Ghent University were the top collaborative institutes.

Conclusion-National Science Foundation (NSF) ranked India as the 3rd biggest knowledge producer in 2020. In this context, this paper will shade light on the contribution of Indian Scientists in the field of Environmental Sciences identifying the most preferred journals, prolific authors and research thrust areas. The prolific authors and their work will certainly influence the new researchers to add new dimensions to their research venture. It will be useful for the researchers and the environmentalists to know the research trend and identify the gap for further study.

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Introduction

There is an emerging interest in using highly cited papers to evaluate research performance. The citation rate measures the impact of scholarly output and gives the publication its due recognition within the scientific community. Highly cited papers are also identified with different terminology, such as most *cited articles* (Lefaivre *et al.*, 2010), *top-cited articles* (Khan and Ho, 2012), *excellent papers* (Bornmann, 2014), and *classic papers* (Huo *et al.*, 2015). The research universities primarily sought their scientific reputation as their merit. The visibility of these universities' scientific achievements through high impact factor journals is the key to assessing their overall research performance (Zhu *et al.*, 2004). Citations are field-specific, individual, and institutional determinants (Antonakis and Lalive, 2009). The analysis of the citation rates of highly cited papers in a specific field reveals valuable information about the growth of that field. Scientists emphasize on the use of normalized citation counts as a base of research assessment because the papers achieve the predetermined threshold for HCAs in different time durations; they may cover various subject fields and diverse document types (Levitt and Thelwall, 2009). Researchers set varied standards for highly cited papers, such as achieving a fixed number of citations from the year of publication to the current year (Khan and Ho, 2012), a certain number of citations of the average papers in that scientific community (Aksnes, 2003), a certain percentile of total publications (Bauer *et al.*, 2016), the number of highly cited articles per researcher (Abramo and D'Angelo, 2015), the citation count of articles to the average world citation in that subject, and the number of years covered (Thelwall, 2019).

Environmental science is an interdisciplinary field that encompasses biology, chemistry, ecology, engineering, geology, meteorology, and physics to study ecological issues and the impact of human intervention on them. Environmental science has experienced tremendous advancements; it marked a new stage in human perception, utilization, and modification of the environment (Ma *et al*., 2020). Out of the 17 Sustainable Development Goals (SDGs) identified by the United Nations, SDG 6 (Clean water and sanitation), SDG 7 (affordable and clean energy), SDG 11 (sustainable cities and communities), SDG 12 (responsible consumption and production), SDG 13 (climate change), SDG 14 (life below water), and SDG 15 (life on land) are directly related to environmental issues. Thus, environmental science and its allied subjects have their own significance in the welfare of society and the protection of the earth.

Among all HEIs, universities are the key players in R&D as they represent a vast source of knowledge, technological capabilities, and cutting-edge research (Berbegal-Mirabent and Ribeiro-Soriano, 2015). Over the past few decades, the theory "publish or perish" played a crucial role in universities and business organizations (Rond and Miller, 2015). The XII five-year plan of India's government emphasized increasing funds for quality-focused efforts, such as more significant allocation of research funds based on quality peer reviews. Furthermore, one of the important parameters determined by the National Institutional Ranking Framework is research and professional practice (RP), which includes the combined metric for publications (PU) and quality of publication (QP).

Related Study

The number of citations received by a peer-reviewed article is often used as a measure of its importance and impact (Tanner-Smith and Polanin, 2016). Researchers have shown keen interest in studying highly cited papers in various disciplines. Several studies were conducted to explore the highly cited articles with distinctive approaches. These studies have covered different fields, such as library and information science (Levitt and Thelwall, 2009; Blessinger and Hrycaj, 2010; Bauer *et al*., 2016), education and educational research (Ivanović and Ho, 2019), and material science (Ho, 2014). Some studies aimed to assess institutional productivity. Peking University, China (Zhu et al., 2004) and 50 universities in the United States (Wohlrabe, Anegon & Bornmann,

2019) were the institutions that were covered under such studies. Some studies have explored highly cited articles in environmental sciences and related subjects. Ma et al. (2020) evaluated 7791 highly cited papers (top 1% of all documents) in environmental sciences from 2009 to 2019. There was an exponential growth in the number of publications during this period. Among the 211 contributing journals, "*Energy & Environmental Science"* were the leading journal. The United States published the highest number of publications. Although the United States was the center of the collaboration network, Mainland China had the highest number of independent research outputs. Khan and Ho identified the top-cited articles from environmental science journals listed in Journal Citation Reports with a minimum of 500 citations. Eighty-eight papers from 26 journals achieved this threshold. *Environmental Science & Technology* and *Water Resources Research* were the most prolific journals, with the USA contributing the highest share of papers. Zhang *et al*. (2019) explored the global trend in ecosystem research based on the Web of Science, analyzing 132 articles that received 100 or more citations. *The top journals were Ecological Economics, PNAS, and Ecological Indicators.* Robert Costanza, Australian National University, was the most productive and highly cited author.

Ribeiro and Atadeu (2019) analyzed the highly cited papers in systematic conservation planning based on the Web of Science from 1989 to 2014. A total of 131 papers were scattered over 25 journals contributed by researchers from 208 institutions based in 25 countries. *The most prolific journal was Conservation Biology and Biological Conservation, with* 11 studies based on information on cost (i.e., economic/land use) and 41 papers including biodiversity data.

Methodology

For the current study, the ten most productive Indian central universities were selected as sample institutes: Aligarh Muslim University (AMU), Banaras Hindu University (BHU), Delhi University (DU), Jamia Milia Islamia (JMI), Jawaharlal Nehru University (JNU), Pondicherry University (PU), Tezpur University (TEZU), University of Allahabad (UoA), University of Hyderabad (UoH), and Visva Bharati University (VBU). Data were retrieved from Scopus on 24th June 2022. Fig. Figure 1 shows the schematic for retrieving highly cited papers (HCPs) in environmental sciences. In Scopus, an “affiliation search” was conducted under the key term “University, India,” which retrieved 986 affiliations. The top 10 central universities were selected from the list based on the total number of publications. The total number of documents produced by these ten central universities was 1, 68,601; the further limit applied was by subject (Environmental Sciences). A total of 12,052 articles were retrieved. Out of these, 9723 were journal articles. $TC_{2021} \geq 100$ (TC_{2021} was the total number of citations since publication until 2021). This set was used as the limit to extract the highly cited papers (N = 306). C_{2021} is the number of citations received in 2021. The number of articles contributed by the first author of the respective university was termed as FAPs.

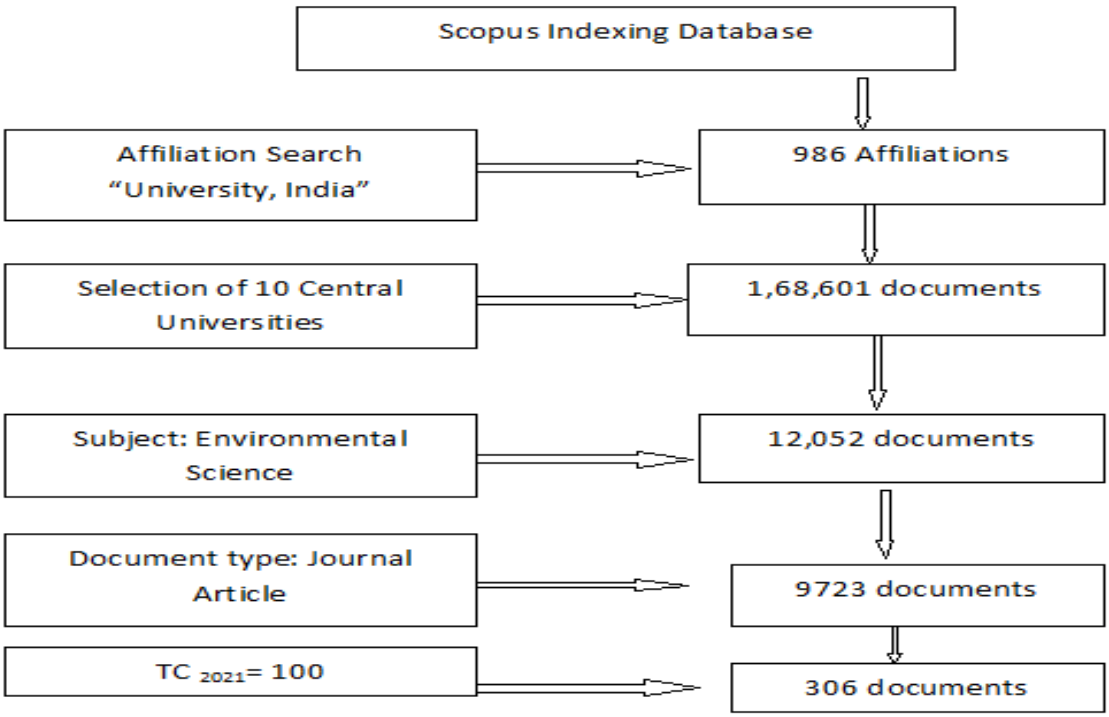

Fig.1 Schematic for data retrieval

Fig. 1 Schematic of data retrieval

Results and Analysis

Fig. 2 shows the chronological growth of group with HCP over 4 decades. A total of 306 articles were published from 1984 to 2020 with a mean citation of 182. The highest number of 152 papers was published during 2001-2010 with average citation of 188, followed by 118 papers (average citation 177) during 2011-2020.

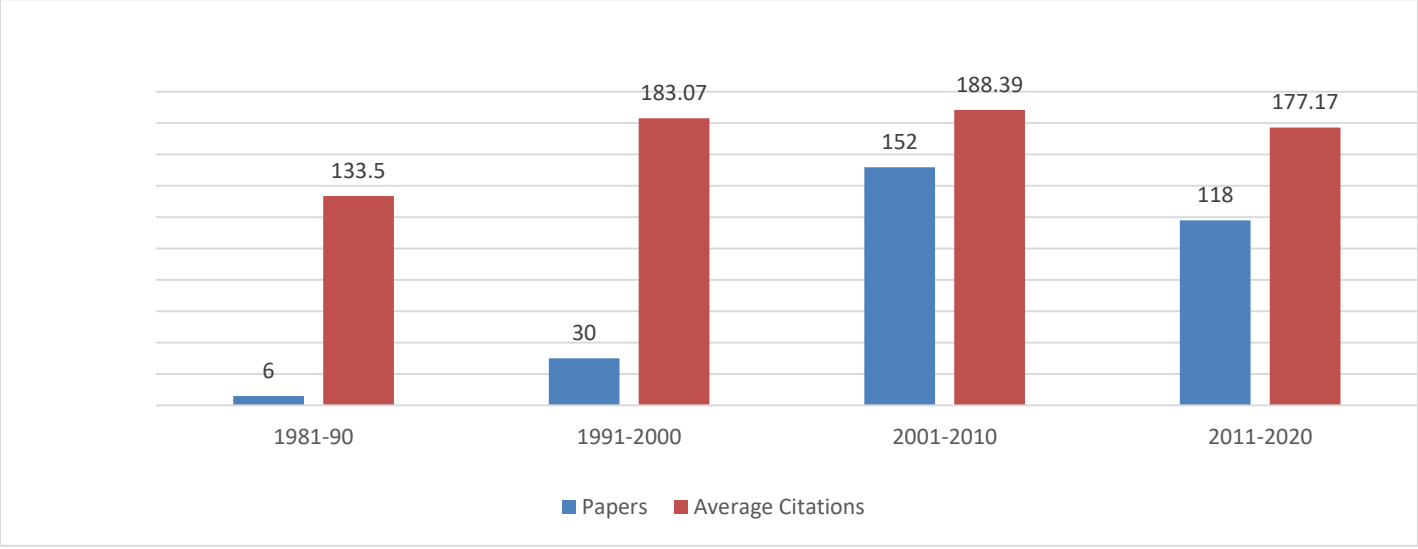

Fig. 2: Decade-wise distribution and average HCP citation

Top Productive Publishers and Journals

These 306 HCP papers were published in 117 scholarly journals and were distributed across 19 publishers. Elsevier contributed 202 papers that were published in 50 journals. The impact factor range of these journals was

2.433–19.503 with a mean of 6.44 as per JCR 2021. *Bioresource Technology and the Journal of Hazardous Materials and Chemosphere* were the prominent journals with 36, 24, and 17 papers, respectively. Springer was the second largest contributing publisher, with 37 papers scattered over 18 journals with a mean IF of 4.21, followed by Wiley, which contributed 11 papers published in 9 journals with a mean IF of 3.68. Table 1 shows the top journals that produced 5 or more papers each.

Table 1: Top productive journals

Journal Name	Frequency	Publisher	IF 2021	APP	CPP
Bioresource Technology	36	Elsevier	9.642	4.00	239.77
Journal of Hazardous Materials	24	Elsevier	10.588	3.33	191.16
Chemosphere	17	Elsevier	7.086	3.12	170.47
Environmental Science and Research on Pollution	9	Springer	4.223	5.67	197.55
Ecological Engineering	7	Elsevier	4.035	3.86	125.57
Ecotoxicology and Environmental Safety	7	Elsevier	6.291	4.29	223.14
Environmental Geology	7	Elsevier	Archived	3.00	158.43
Green Chemistry	7	RSC	10.182	4.00	146.86
Science of the Total Environment	7	Elsevier	7.963	4.43	161.86
Chemical Engineering Journal	6	Elsevier	3.978	5.33	224.33
Applied and Environmental Microbiology	5	ASM	4.792	6.20	239.4
Environmental Monitoring and Assessment	5	Springer	2.513	3.00	174.8
Environmental Pollution	5	Elsevier	8.071	3.00	215.8
Waste Management	5	Elsevier	7.145	4.00	374.60
Water Research	5	Elsevier	11.236	3.00	237.80

APP: author per paper; CPP: citation per paper

Authorship Pattern and Impact of Citation

Figure 3 shows the distribution of papers among different authorship patterns and their impact. The authorship pattern is categorized into single-authored papers (SAPs), multi-authored papers (MAPs), i.e., papers contributed by 2 to 5 authors, mega-authored papers by 6 to 10 authors and papers contributed by more than 10 authors. The highest number of 244 papers was multi-authored. However, among the MAPs, 77 were three-authored papers. Figure 3 shows that the papers with more than 10 authors had the highest visibility, achieving the highest mean citation of 219.18, followed by single-authored papers with 202.64 citations per paper.

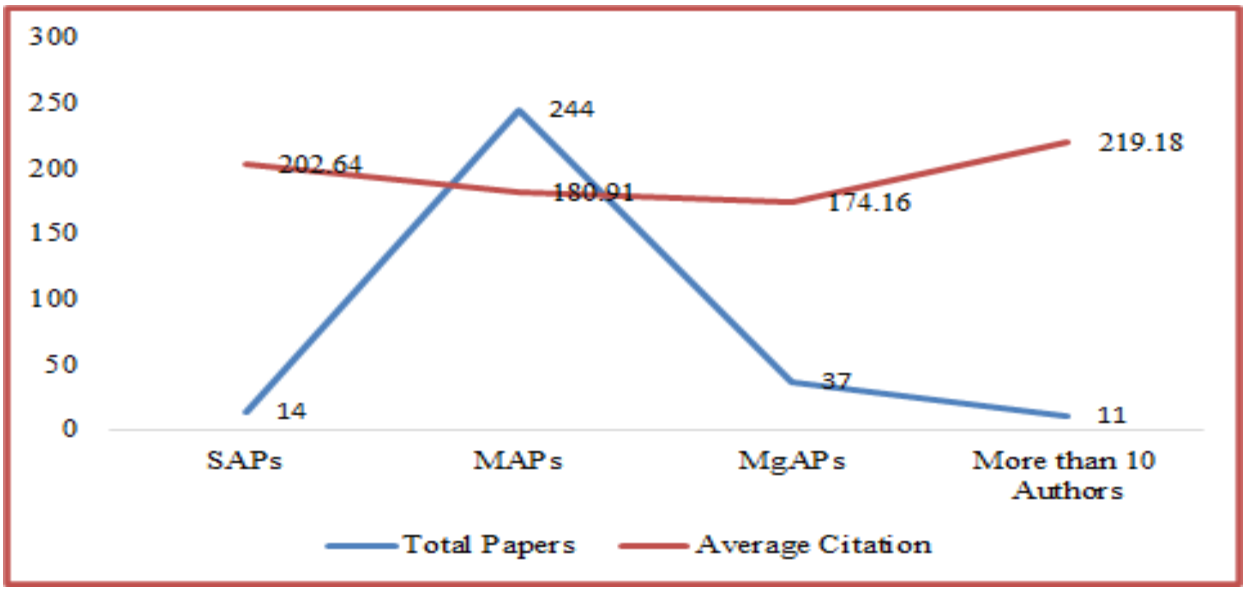

Fig. 3: Authorship pattern-wise impact of the HCPs

Top Productive Authors

A total of 1825 authors appeared 2202 times. The top 24 authors had published a minimum of 5 papers each. Table 2 lists the top 10 authors who have published at least 6 papers. Out of them, 8 authors were from different Central Universities (2 authors each from AMU, BHU, and DU, and one author each from JNU and JMI). Two collaborating authors from other institutions, including S. Singh from the National Physical Laboratory, New Delhi and C.U. Pittman, Department of Chemistry, Mississippi State University. M Agrawal from Banaras Hindu University contributed highest 14 papers and was the most prolific author with an h-index of 14. Together, these 10 authors contributed 28% of the total highly cited papers. The 1st author of a paper is attributed with the most significant contribution toward the publication, here Ali I, Department of Chemistry, Jamia Milia Islamia contributed the highest number of 8 FAPs (73%).

Table 2: Top productive authors

Sl. No.	Author with affiliation	TP	FAPs	CAPs	h-index	m-index	TC
1	M. Agrawal, Department of Botany, Banaras Hindu University	14	0	10	14	0.424	3625
2	D. Mohan, Department of Environmental Science, Jawaharlal Nehru University	12	4	4	12	0.923	4347
3	I. Ali, Department of Chemistry, Jamia Milia Islamia	11	8	7	11	0.647	2160
4	RC, Kuhad, Department of Microbiology, University of Delhi	8	1	6	8	0.348	1568
5	S. Kumar, Department of Botany, University of Delhi	8	2	0	8	0.400	1185

6	A. Ahmad, Department of Botany, Aligarh Muslim University	7	0	0	7	0.269	1450
7	R. Ahmad, Department of Applied Chemistry, Aligarh Muslim University	7	3	0	7	0.292	1839
8	CU Pittman, Department of Chemistry, Mississippi State University	7	0	0	7	0.538	2975
9	RP Singh, Department of Botany, Banaras Hindu University	6	0	0	6	0.353	1706
10	S. Singh, National Physical Laboratory, New Delhi, India	6	0	0	6	0.353	1342

FAPs: first author papers, CAPs: corresponding author papers

University-wise distribution of the HCPs

Out of the total papers, 151 (almost 50%) were contributed by one or more central universities out of intra-university and inter-university collaboration, 90 are internationally collaborated papers with 75 countries, and 65 are national collaborative papers. This reveals that internal collaboration is higher than national collaboration, which is a good indicator of quality research.

Together, the 10 central universities contributed 202 first-author papers (FAPs). BHU produced the highest number of FAPs, 139 of which 43 were FAPs. AMU and DU produced 37 and 33 first-author papers, respectively. There were 81 FAPs from different countries and 23 from various national organizations. BHU collaborated with other national institutions to produce 11 papers, and JNU collaborated with international institutions to contribute 25 ICPs. Table 3 shows the productivity of the central universities in different categories.

Table 3: University-wise publications

University	TP	FAPs	NCPs	ICPs	SAPs
BHU	139	43	11	15	01
JNU	97	29	10	25	05
AMU	92	37	01	12	02
DU	70	33	12	14	04
UoA	44	12	3	4	Nil
PU	36	10	01	4	01
TEZU	33	10	06	1	Nil
JMI	30	15	05	4	01
VBU	22	9	01	1	Nil
UoH	13	4	01	4	Nil

Collaborative Countries and Institutions: The central universities collaborated with 550 institutions in India and overseas. In collaboration with 75 countries, they produced 90 papers, which accounted for 29.41% of the total publications with 612 mean citations. In addition, 19 countries contributed 79 corresponding authors' papers. The Central universities collaborated with the USA in 30 papers, of which 8 were corresponding author papers. The top institutes that produced 11, 10, and 6 collaborative papers with central universities were King Saud University,

Saudi Arabia, Mississippi State University, USA, and Ghent University, Belgium. Among 124 national collaborative organizations, the Radio and Atmospheric Sciences Division of National Physical Laboratory, New Delhi; Amity Institute of Microbial Technology, Uttar Pradesh; and Central Ground Water Authority, Jamnagar House, Delhi were the prominent collaborators. The total number of national collaborative papers was 65. Table 4 and Figure 3 depict the top 14 countries that each contributed a minimum of 5 papers each in collaboration with the central universities.

Table 4: Top Collaborative Countries

Country	Total Publications	Total Citations	Corresponding Author Publications	Corresponding Authors' Citations
United States	30	6579	8	1144
United Kingdom	18	3956	8	1820
China	13	2732	7	1127
Saudi Arabia	13	2310	6	950
Germany	9	1615	4	861
Japan	8	1184	1	107
South Korea	8	3120	6	950
Canada	7	1259	2	255
Belgium	6	1088	2	428
Italy	6	925	0	0
Spain	5	1118	0	0
Portugal	5	767	4	542
Australia	5	740	1	113
Brazil	5	664	2	257

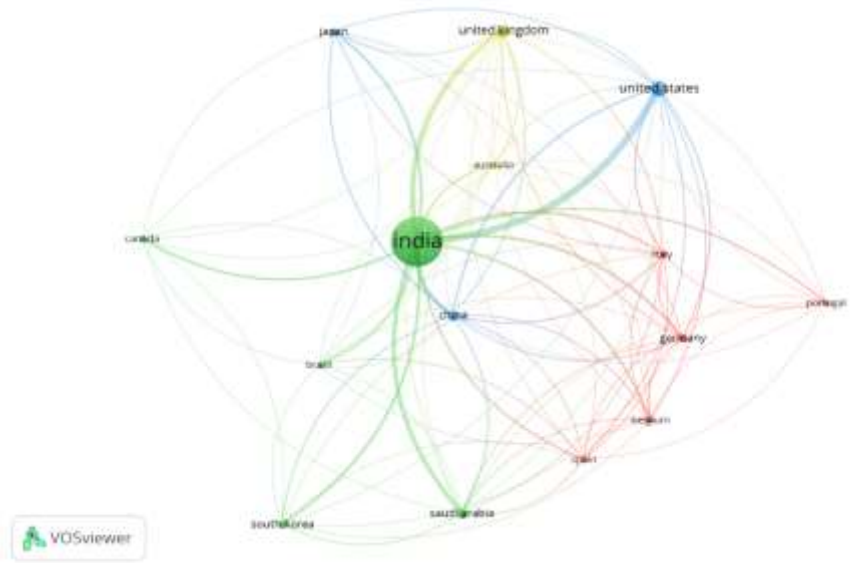

Fig. 3: Collaboration of central universities with the top 14 countries

Keywords Most Occurred

A keyword is an instrument that retrieves the most relevant paper(s) from a large number of publications. The selection of suitable keywords increases the visibility of the paper, which may lead to citations. A total of 1100 author keywords were used in the current set of papers (Fig. 4). Sixteen keywords that occurred more than 5 times

each identified the main areas of research in environmental science. The most commonly used keywords were heavy metals, adsorption, and toxicity with frequencies of 23, 19, and 11, respectively. Figure 4 reveals the major thrust areas of the papers.

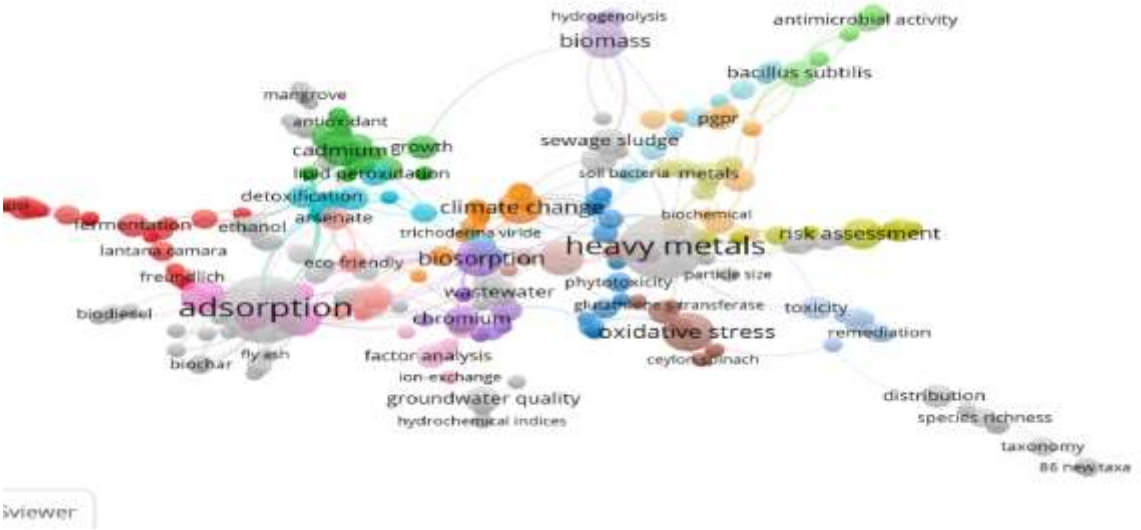

Fig. 4 Keywords mapping

Top 10 highly cited papers

Table 6 lists the top 10 highly cited papers published from 1998 to 2015 in 7 scholarly journals, 2 papers from each year 2007, 2008, and 2012. *Bioresource Technology* was the most prominent journal with 36 articles; it had contributed 3 papers that were among the top 10 papers. *Waste Management contributed* 2 papers. The minimum impact per paper was 691.2. The 1st paper authored by Dinesh Mohan, Jawaharlal Nehru University, was a review of the application of biochar in water and wastewater treatment. The 2nd paper authored by F. Zahir, Shamim J Rizwi, Soghra K Haq, and Rizwan H Khan of Aligarh Muslim University studied how low mercury adversely affected the health and caused various types of disorders, such as neurological, nephrological, cardiac, motor, reproductive, immunological, and genetic disorders. The 3rd publication was also a review paper authored by R. P. Singh and M Agrawal of Banaras Hindu University studied the available information on the application of sewage sludge/biosolids, which is a byproduct of sewage treatment for agronomy and horticulture.

Table 6 Top 10 highly cited papers

Sl. No.	Title	First Author	Year	Source Title	TC
1	Organic and inorganic contaminants removal from water with biochar, a renewable, low cost and sustainable adsorbent: A critical review	D. Mohan, JNU	2014	Bioresource Technology	1418
2	Low dose mercury toxicity and human health	F. Zahir, AMU	2005	Environmental Toxicology and Pharmacology	823
3	Potential benefits and risks of land application of sewage sludge	R.P. Singh, BHU	2008	Waste Management	768
4	Effects of pyrolysis temperature on soybean stover- and peanut shell-derived biochar properties and TCE adsorption in water	M. Ahmad, Kangwon National University, South Korea	2012	Bioresource Technology	767

5	Heavy metal contamination of soil and vegetables in suburban areas of Varanasi, India	R. Kumar Sharma, BHU	2007	Ecotoxicology and Environmental Safety	643
6	Municipal solid waste management in Indian Cities: A Review	M. Sharholy, JMI	2008	Waste Management	614
7	Effect of salinity stress on plants and its tolerance strategies: a review	S Singh, UoA	2015	Environmental science and pollution research	528
8	Crude petroleum-oil biodegradation efficiency of Bacillus subtilis and Pseudomonas aeruginosa strains isolated from a petroleum-oil contaminated soil from North-East India	K. Das, TEZU	2007	Bioresource Technology	486
9	Role of sawdust in the removal of copper (II) from industrial wastes	M. Ajmal, AMU	1998	Water Research	435
10	Progress and trends in CO2 capture/separation technologies: A review	M. K. Mondal, BHU	2012	Energy	430

Findings and Conclusions

Most of the ranking systems are complex exercises that evaluate not only the total number of publications but also their quality in terms of citations received and the repute of the journals (Impact Factor) in which they are published. As the Indian central universities are the torch bearer of various research programs initiated by the government of India, the evaluation of the scholarly performances of the central universities carries its own significance and tempts the researchers to study the research activities of the central universities. Out of the 17 Sustainable Development Goals (SDGs) identified by the United Nations, SDG 6 (Clean water and sanitation), SDG 7 (affordable and clean energy), SDG 11 (sustainable cities and communities), SDG 12 (responsible consumption and production), SDG 13 (climate change), SDG 14 (life below water), and SDG 15 (life on land) are directly related to environmental issues. In this context, the present paper will illuminate how far the research communities of central universities contribute to achieving the SDGs in partnership with their national and international collaborators. The study revealed that the contribution of Central universities in the domain of environmental science was commendable, which was reflected in the form of 306 HCPs scattered over 117 scholarly journals with IF ranging from 0.781 (Journal of Environmental Biology) to 15.836 (Fungal Diversity). These universities collaborated with 550 national and international institutions in 75 countries to produce 90 ICPs with 11,276 citations and 124 national organizations contributed 65 NCPs with 4656 citations. Although the volume of internal collaborations was higher than that of local and national collaborations, the prominence of national collaborative papers was quite significant. Hence, central universities/researchers should enhance their collaboration with their national partners.

The current paper will help researchers in the field of environmental sciences identify the most preferred journals in the discipline of environmental sciences that incorporate nascent ideas in research. They can develop insight into the burning topics in which work has been done, identify the research gap, and get motivated to carry their research in a new direction. The prolific authors and their works will certainly influence new researchers to add new dimensions to their research ventures.

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