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Solid Waste Research in India during 2008-2017: A Bibliometric Analysis

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Abstract

This paper presents a bibliometric overview of Indian researchers publications published on “Solid Waste” in the Web of Science database from 2008 to 2017. Several aspects have been analyzed in the study; such as the growth and distribution of solid waste research in India, the most productive organization/institution in India, authorship pattern, document type, the high frequency of authors’ keywords, measuring the source of publications, and the international collaboration in India’s research output and so on. The highest number of contributions has been recorded in 2017 alone 216 papers, (21.49%) published and the lowest was 2008 with 71 papers, (7.06%). The study has revealed that the publication growth increased progressively from 2008 to 2017. Kumar S (30 papers; TLCS 54; TGCS 411) is been the most productive author out of the total 3609 authors. The maximum number of articles 855 (85.07%) in total are published in the journals. It has been found that ‘Waste Management (79, 7.9%)’ was the most preferred journal of the Indian researchers. The Indian authors have major collaborations with the USA, China, South Korea, Saudi Arabia, Germany, Japan and the UK.

Keywords: Solid Waste, Bibliometric Analysis, Authorship Pattern, Web of Science, India.

Introduction:

Solid waste is nothing but the unwanted product/produce or unwanted solid materials which are not in the state of liquid or gas forms produced out of human activities in our surroundings from the area of residential, commercial or industrial. It may be broadly classified into two ways which are based on their source of origin (domestic, commercial, industrial, institutional, municipal, agricultural etc..) and based on physical nature (garbage, ashes, combustible and non-combustible, demolition and construction and hazardous etc). Solid Waste Management eliminates the adverse impact on the environment & human health. These solid wastes are necessary to manage the manufactured goods both public health and the environment as well. Moreover, “solid waste management represents an essential element of sustainability and environmental protection. Social acceptance, economic efficiency,

organizational matters, water, soil and air pollution are among the most important issues confronted in projects, either already realized or planned in the near future” (Tolis et al. 2010).

Bibliometrics is a set of techniques used to qualitatively and quantitatively assess the academic quality of published literature of an individual researcher, institutions, journals or countries by application of statistical methods. These bibliometric tools are effectively used by information managers to analyze the publication growth rate, productive contributors, impact factor, citations, h index and future requirements in a particular discipline. This analysis helps to formulate a well defined objective for conducting high quality research to find out the latest trends and hot spots in solid waste research in India. It also provides an idea about which journals, institutions and countries have high impact in the specific field of knowledge.

Numerous studies were undertaken consequently results were published on different aspects of solid waste management in various journals from all over the world. However, no systematic analysis of solid wastes research has not undertaken in India so far. So, we have made an attempt to conduct the bibliometric analysis on “Solid Waste” research in India during the period 2008-2017 to find out the literature growth rate, authorship pattern, and degree of collaboration, prolific institutions, citation, impact factor, frequency of keywords and international collaborations.

Objectives

The main objectives of the study is to analyze the following bibliometric characteristics of the solid waste research in India (2008-2017)

- To examine year wise literature growth on solid waste research in India
- To identify the most prolific authors
- To examine the authorship pattern of the contributions
- To identify the degree of collaboration
- To examine the year wise distribution of citations
- To identify the most productive organization/institution in India
- To find out the high frequency author keywords
- To measure document-type distribution
- To find out the international collaboration in India’s research output

Literature Review

Adesina and Opesade (2018) have conducted an analysis of Sickle cell anaemia research publications on Nigeria listed in PubMed during the period 2006 to 2016. A total of 326 publications taken for study and literature growth rate have been increased between the years 2006 and 2010. However, the research publications on Sickle cell have been decreased between the years 2011 and 2015. It indicates the research on this specific field has slowly come down the recent years in Nigeria. University of Nigeria Teaching Hospital had contributed the highest number of publications. Degree of collaboration varies from 0.85 to 1.00 and the majority of authors had contributed from Nigeria.

Mesdaghinia, et. al. (2015) has evaluated the Scopus indexed solid waste related papers produced by Iran from 1982 to 2013. The exponential trend ($R^2 = 0.98$) had increased growth rate by 45.3 % per year between the years 1982 to 2011. The Journal of Environmental Studies has published the highest number of papers. The maximum collaboration has found among the main universities in Iran and other institutions play fewer roles in the contribution of papers related to solid waste.

Li, Han and Lu (2018) have presented the analysis to trace the research trends on solid waste recycling and reuse was performed on the literature available in Science Citation Index (SCI) during the period 1992 to 2016. The results have demonstrated a rapid growth rate in research outputs with large international collaboration. Further, production of biodiesel from waste oil and recycling of e-waste are two emerging hot issues from 2002 to 2007.

Ma, Ho and Fu (2011) have conducted a study on solid waste interrelated research publications in the Science Citation Index Expanded (SCIE) from the Web of Science database during the period from 1991 to 2010. The G7 countries played a vital role in publication. From the analysis of keywords, authors find that recycling, composting, waste-to-energy and landfill have been the common solutions for waste management problems. Anaerobic digestion, heavy metals and sewage adsorption are considered as hot spots.

Fu, H. Z. et. al. (2010) have carried out a bibliometric analysis of 6680 solid waste theme related publications available in the Science Citation Index from Web of Science database from 1993 to 2008. In this analysis mainly concentrated the frequency of title-words, 'Keywords Plus' and author keywords to provide research emphasis.

Qiu and Chen (2009) have conducted a bibliometric analysis of all biological invasions on the data from SCI Web of Science Database from 1991 to 2007. A total of 3323 documents were published by 7261 authors from 521 journals of 100 countries taken for study. Citation per publication (CPP) used as an indicator for evaluating the data and collaboration among the biological invasions related research literature in Japan & China, which was not as effective as that of Latin America and South Africa based on the CPP study.

Maharana (2014) has analyzed the Indian researcher's publications indexed in Web of Science (WoS) bibliographic database on malaria research during the period 2003 to 2012. This study presents 2020 research documents with 48 h index and the maximum researchers preferred articles (81.43 %) as main source of information. Most productive journal was "Malaria Journal" with 97 papers and major research disciplines were "Tropical medicine" and "Parasitology". CSIR have been the main funding agency in India in terms of providing research grants. The research on malaria in India has been increased steadily during this period.

Alagu and Thanuskodi (2019) have examined by using the Hiscite software on the digital literacy related publications, indexed in Web of Science (WoS) bibliographic database between the years 1992 to 2011. The highest (126) number of research publications have been published in the year 2011 out of the total publications 512. This Analysis shows the most productive country is USA followed by UK and Australia in research publications growth in digital literacy.

Methodology

The data used in this present study have been taken on 19th August 2018 from the ISI Web of Science comprehensive interdisciplinary, bibliographic database published by Clarivate Analytics. For retrieval of information, the term "solid waste" has been used as a keyword and "India" was used as author's affiliation and "2008-2017" has been taken as the period for study. A total of 1005 documents have been downloaded and used the Bibexcel, Microsoft-Excel and Pajek software for the purpose of data analysis. In addition, collaboration networks have been generated by using VOSviewer software. Impact factor (IF) values have been taken from the world famous citation database Journal Citation Report (JCR) published in 2016.

Data analysis and interpretation

Table.1 Year wise Distribution of Literature Published on Solid Waste Research in India

Sl. No	Year	No. of Publications	Percentage	Cumulative	Percentage
1.	2008	71	7.06	71	7.06
2.	2009	60	5.97	131	13.03
3.	2010	74	7.36	205	20.40
4.	2011	85	8.46	290	28.86
5.	2012	61	6.07	351	34.93
6.	2013	78	7.76	429	42.69
7.	2014	80	7.96	509	50.65
8.	2015	132	13.13	641	63.78
9.	2016	148	14.73	789	78.51
10.	2017	216	21.49	1005	100.00
Total		1005	100		

The year wise distribution of publication on “solid waste” research in India shows in the above Table 1. A total of 1005 papers were published by the authors from all over India during the ten years period of study. An average of 100 papers published on this topic per year. The study exposes that 71 papers published with an average of 7.06% in 2008 and 216 papers with an average of 21.49% in 2017, from which it is clear the growth rate of publication pattern which has gradually increased more than three times in the last ten years span of time. The highest number of contributions has been recorded in 2017 (216 papers, 21.49%) and the lowest has been in 2008 (71 papers, 7.06%). The cumulative total of publications and percentage for each year has also been given. The literature on the topic of “solid waste” has increased well progressively in India.

Table.2 Year Wise Growth of Publication

Year	No. of Publications	Growth Rate	Average Growth Rate Percentage
2008	71	0	0
2009	60	-11	-15.49
2010	74	14	23.33
2011	85	11	14.86
2012	61	-24	-28.24
2013	78	17	27.87
2014	80	2	2.56
2015	132	52	65.00
2016	148	16	12.12
2017	216	68	45.95
Total	1005	145	Average=14.79

Annual growth of publication

To get an overview of literature growth, the number of published papers during 2008-2017 is shown in Table 2. A total of 1005 research publications published with the average growth rate of 14.79% (total growth rate/number of years). From this table, we can also find that the years 2009 & 2012 growth rate is been negative. The highest publication growth rate is recorded in 2015 with 65% followed by in 2017 with 45.95%. Year wise growth rate is been found out with the help of following formula:

$$r = \frac{P1-P0}{P0} \times 100$$

Where, r = Publication growth in percentage

P0 = Number of publication in the base/ previous year

P1 = Number of publication in present year

Table.3 Top ten prolific authors with number of papers

Sl. No	Authors	No. of Publications	Percentage of Publications	TLCS	TGCS	h-index
1.	Kumar S	30	3.0	54	411	11
2.	Sekaran G	22	2.2	45	287	11
3.	Kumar A	15	1.5	6	70	5
4.	Kazmi AA	13	1.3	22	199	7
5.	Babu GLS	12	1.2	10	61	5
6.	Bhattacharyya P	12	1.2	23	146	8
7.	Siddique R	12	1.2	0	502	10
8.	Awasthi MK	11	1.1	27	205	7
9.	Kalamdhad AS	11	1.1	18	193	7
10.	Garg VK	10	1.0	17	145	5

TLCS: Total Local Citation Score, TGCS: Total Global Citation Score

Table 3 presents the top ten productive authors out of a total of 3609 authors according to the number of research publications they have published in the study period 2008-2017. The most productive authors is Kumar S (30 papers; average 3.0; TLCS 54; TGCS 411) followed by Sekaran G (22 papers; average 2.2; TLCS 45; TGCS 287). The high TGCS have got by Siddique R (12 papers; TGCS 502). The top two authors also have high h index 11, followed by Siddique R with h index 10, which denote they have received the high authority based on their publications published in the selected field. The publications h-index value varies 11-5 for the top ten authors.

Table.4 Distribution of Authorship Pattern

No. of Authors	No. of Publications	Total No. of Authors	Percentage
1	31	31	3.08
2	283	566	28.16
3	280	840	27.86
4	156	624	15.52
5	124	620	12.34
6	65	390	6.47
7	27	189	2.69
8	20	160	1.99
9	10	90	1.00
10	5	50	0.50
11	2	22	0.20
12	1	12	0.10
15	1	15	0.10
Total	1005	3609	100.00

Table 4 reflects the authorship patterns of contributions. It is observed that 96.92% of papers were contributed by multi authors. Out of 1005 contributions, the highest number of contribution made by double authors and it accounts for 283 with 28.16% followed by three authors contributions with 280 (27.86%). 15.52% of the contributions are made by four authors. 12.34% of contributions are published by five authors.

Degree of collaboration:

Subramanyam (1983) proposed a formula to calculate the degree of collaboration in quantitative as follows:

$$\text{Degree of collaboration (DC)} = \frac{N_m}{N_m + N_s}$$

N_m = Number of multi-authored papers

N_s = Number of single-authored papers

As a result, the degree of collaboration is $974/1005 = 0.97$.

Table 4 also is displayed that out of a total 1005 papers multi-authored papers were 974 (DC 0.97), it shows the majority of the papers published with collaboration and single-authored papers are very less only 31 (DC 0.30). The highest DC 0.97 explains the collective works and sharing of information among the researchers in the field of solid waste research in India.

Table.5 Year-wise distribution of citations

Year	Number of Publications	Number of Citations	ACPI
2008	71	2476	34.87
2009	60	3702	61.70
2010	74	2549	34.45
2011	85	1753	20.62
2012	61	923	15.13
2013	78	1137	14.58
2014	80	945	11.81
2015	132	1282	9.71
2016	148	877	5.93
2017	216	538	2.49
Total	1005	16182	16.10

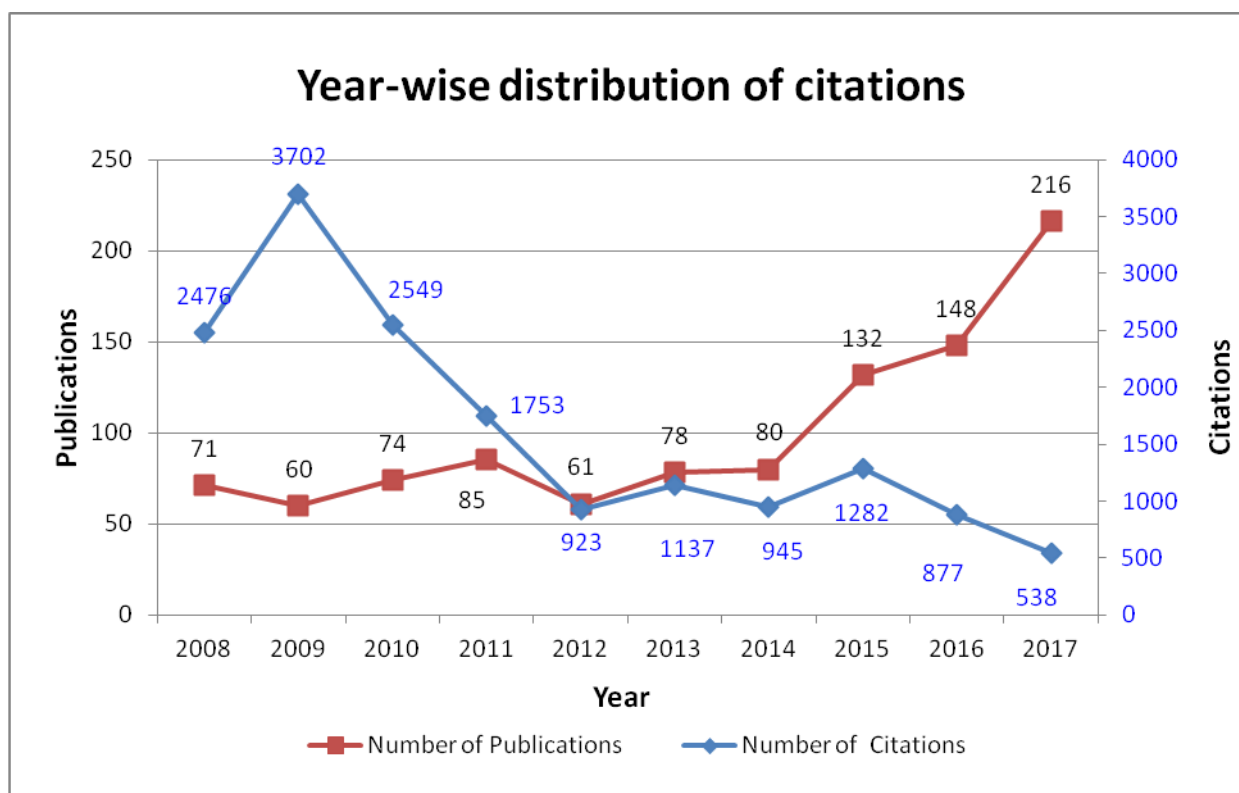


Figure. 1 Year-wise distribution of citations

Analysis of citations:

The references provided by the authors at the end of their research paper reflect the source of citation analysis. The citation analysis process involves counting the number of citations to a research paper for a fixed period of years after its publication. Table 5 and Figure 1 demonstrates 16,182 citations which have got over a ten years study period for the total publications of 1005 papers. The maximum number of citations 3702(ACPI 61.70%)

received in 2009 followed by 2476 (ACPI 34.87%) citations in 2008 and the minimum number of citations are 538(ACPI 2.49%) in the year 2017. The average citation per publication (16.10%) has observed during the study period.

Table.6 Publication, Citation, H-index and Impact Factor of Top 25 Journals (2008-2017)

Sl. No	Journal	TP (%)	TC	H-index	IF (2016)
1.	Waste Management	79(7.9)	1721	21	4.03
2.	Bioresource Technology	53(5.3)	1971	21	5.651
3.	Waste Management & Research	36(3.6)	195	9	1.803
4.	Journal of Cleaner Production	24(2.4)	364	9	5.715
5.	Environmental Science and Pollution Research	20(2)	195	8	2.741
6.	Journal of Hazardous Materials	19(1.9)	1244	14	6.065
7.	Resources Conservation and Recycling	18(1.8)	481	15	3.313
8.	Environmental Monitoring and Assessment	18(1.8)	405	11	1.687
9.	Renewable & Sustainable Energy Reviews	17(1.7)	671	13	8.05
10.	Clean Technologies and Environmental Policy	15(1.5)	89	6	3.331
11.	Desalination and Water Treatment	15(1.5)	91	4	1.631
12.	International Journal of Environmental Science and Technology	13(1.3)	127	5	1.915
13.	Journal Of Environmental Management	12(1.2)	1795	9	4.01
14.	Construction and Building Materials	12(1.2)	359	8	3.169
15.	Ecotoxicology and Environmental Safety	12(1.2)	201	8	3.743
16.	Journal of Environmental Biology	12(1.2)	49	5	0.697
17.	Environmental Technology	12(1.2)	51	4	1.751
18.	Current Science	12(1.2)	32	3	0.843
19.	Chemical Engineering Journal	9(0.9)	483	8	6.216
20.	Ecological Engineering	9(0.9)	189	8	2.914
21.	Journal Of Material Cycles And Waste Management	9(0.9)	62	5	1.604
22.	RSC Advances	9(0.9)	62	5	3.108
23.	Journal Of Environmental Chemical Engineering	9(0.9)	61	4	
24.	Global Nest Journal	9(0.9)	13	2	0.665
25.	Clean-Soil Air Water	8(0.8)	217	7	1.473

Table 6 lists the top 25 most productive journals with their total publications, citation, h-index and impact factor. The top 25 journals included approximately 45% of the total number of publications (n = 461, 45.87%). The Waste Management (79, 7.9%), Bioresource Technology (53, 5.3%) and Waste Management & Research (36, 3.6%) are the top three journals contributing more than 30 documents each. However, of the top 25 journals, only one journal

doesn't have an impact factor. The 'Chemical Engineering Journal' and has got highest impact factor (IF= 6.216) in 2016, followed by the Journal of Hazardous Materials (IF=6.065) and Journal of Cleaner Production (IF = 5.715).

Table.7 the Top Ten Prolific Institutions with Number of Publications

Sl. No	Institution	Publications*	Percentage
1.	Central Leather Research Institute (CLRI), Chennai	71	7.06
2.	Anna University, Chennai	51	5.07
3.	Jadavpur University, Kolkata	30	2.99
4.	Indian Institute of Technology Delhi, New Delhi	28	2.79
5.	National Environmental Engineering Research Center, Chennai	24	2.39
6.	Indian Institute of Science, Bangalore	22	2.19
7.	National Institute of Technology, Tiruchirappalli	21	2.09
8.	Banaras Hindu University, Varanasi	16	1.59
9.	Jawaharlal Nehru University, New Delhi	15	1.49
10.	Pondicherry University, Puducherry	14	1.39

*Total number of publications 1005

The top 10 most productive institution/organization are shown in Table 7. The study exposed the Central Leather Research Institute (CLRI) with 71 publications (7.06%) which is the most productive institution/organization, followed by Anna University (51, 5.07%). Jadavpur University 30 (2.99), Indian Institute of Technology, Delhi 28 (2.79%) and National Environmental Engineering Research Center 24 (2.39%) contributions are stood at the third, fourth and fifth position respectively.

Table.8 Top 15 frequency of author keywords used

Sl. No	Author Keywords	Frequency
1.	Municipal Solid Waste	93
2.	Adsorption	59
3.	Kinetics	52
4.	Solid waste	42
5.	Heavy metals	38
6.	Biogas	35
7.	Leachate	35
8.	Solid waste management	30
9.	Isotherms	30
10.	Anaerobic digestion	28

11.	Landfill	26
12.	Composting	25
13.	Isotherm	19
14.	Fly ash	19
15.	Vermicomposting	18
16.	Recycling	17
17.	Compressive strength	17
18.	Biosorption	16
19.	Methane	15
20.	India	15

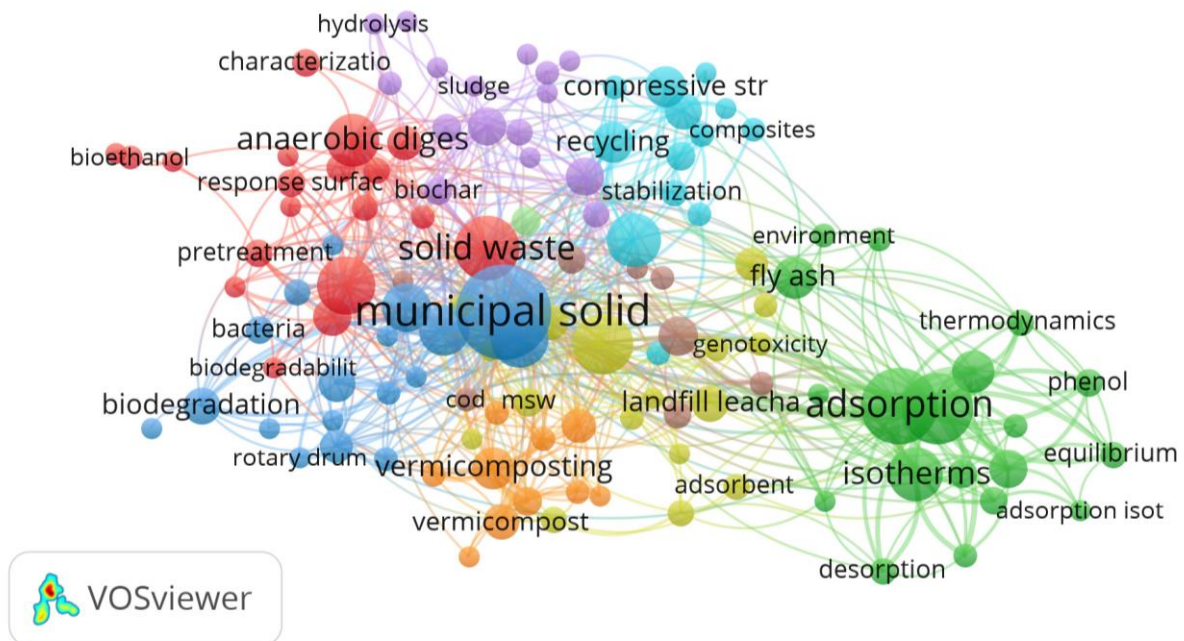


Figure. 2 VosViewer mapping of most frequent author keywords in Solid Waste

Table 8 and Figure 2 shows the top 15 most frequently used author keywords emerged in “solid waste” research in India. The frequency of keywords represents the latest developments in that particular field and “Municipal Solid Waste, Adsorption, Kinetics, Solid waste, Heavy metals, Biogas” keywords which are getting more importance in solid waste research in India.

Table.9 Distribution of document types

Sl. No	Document Type	No. of Publications	Percentage	Citations	h index
1.	Article	855	85.07	9982	43
2.	Review	117	11.64	6194	33
3.	Editorial Material	25	2.49	4	1
4.	Meeting Abstract	3	0.3	0	0
5.	Correction	3	0.3	1	1
6.	Letter	2	0.2	1	1
Total		1005	100	16182	

Table 9 reveals the distribution of research publications in terms of the document type. The distribution of documents types has been analyzed and resulted in 6 document types, within a total of 1005 publications. Majority of the authors preferred document type of article with 855 articles (85.07 %), followed by Review (117, 11.64%), Editorial Material (25, 2.49%), Meeting Abstract (3, 0.3%), Correction (3, 0.2%) and Letter (2, 0.2%). The study reveals that articles has got highest number of citations (9982) and h index (43).

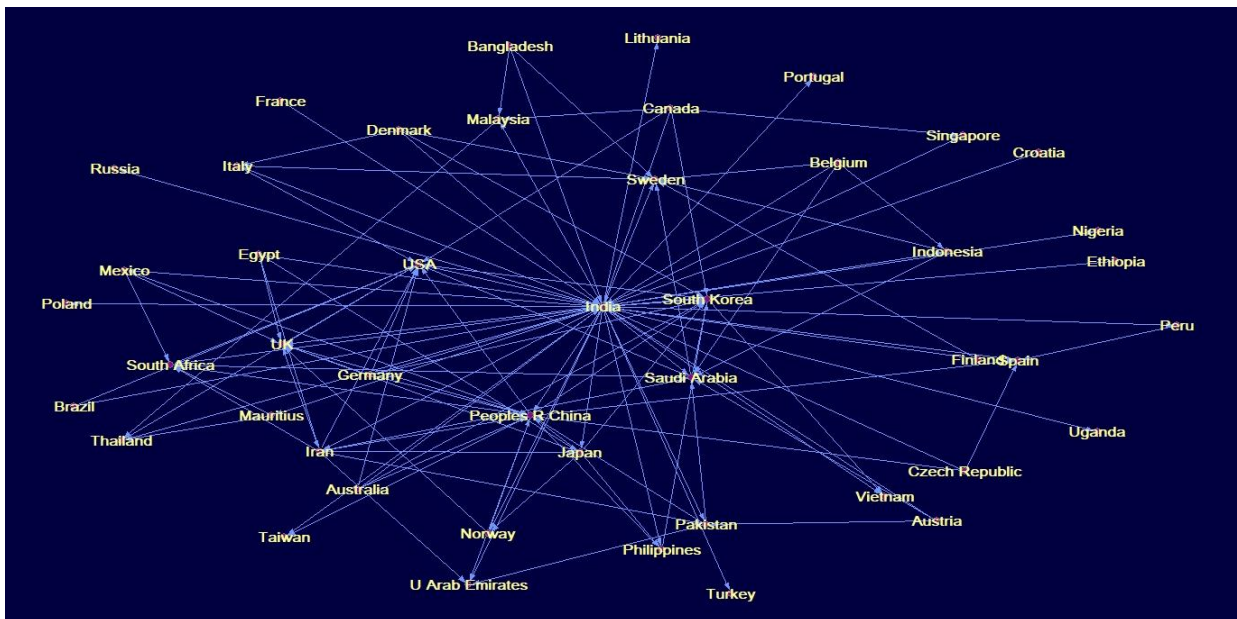


Figure. 3 Bibliometric network map of India’s international collaboration

Figure 3 illustrates bibliometric network map of India’s international collaboration. The whole network consists of 45 nodes represents the number of countries, most of which are scattered. It can be seen that India has centered and a major collaboration with the USA, China, South Korea, Saudi Arabia, Germany, Japan and the UK.

Summary and Conclusion

This present study gives a general overview of the published literature on solid waste research in India between the years 2008 to 2017. A total of 1005 publications data were collected from Clarivate Analytics published in Web of Science bibliographic database during the study period. The study explains that 71 papers published with an average of 7.06% in 2008 and 216 papers with an average of 21.49% in the year 2017, from which it is clearly indicate the growth rate of publication pattern has gradually increased more than three times in the last 10 years span of time and also observed that an average of 100 papers published on this topic per year. The highest degree of collaboration 0.97 shows the collective research works and the sharing of information among the authors in the field of solid waste research. This study also demonstrates citation, h-index and impact Factor of top 25 Journals and ‘Waste Management (79, 7.9%)’ is the most preferred journal related to solid waste discipline. From this analysis, Central Leather Research Institute (71, 7.06%) has highest contributions and also identified “Municipal Solid Waste, Adsorption, Kinetics, Solid waste, Heavy metals, Biogas” is appeared as central keywords in solid waste research in India. The significance of literature growth on solid waste research in India indicates the ideology of Indians towards solid waste recycling and reuse to protect the environment. This study would enable for those who are doing further research on Solid Waste Management and related to environmental engineering as well in the near future.

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