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Prakash waghmare
vagmare@gmail.com

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Bibliometric Analysis of Global Research Trends on E-Waste Management from Scopus Database seen through Biblioshiny

By

Dr. Prakash Waghmare
Librarian Government First Grade College Manhalli
Tq and Dist: Bidar 585403
E-mail: vagmare@gmail.com

Abstract

The present study analyzed 534 global publications in e-waste management indexed by Scopus database. The data was analyzed using biblioshiny app. Very few bibliometric studies were found on e-waste management using biblioshiny application. Further, the paper presented three fold relation viz, authors, countries and keywords, authors and source impact, word count and word growth with thematic presentation and collaborative network of documents. The highest contribution in e-waste management research is published in the form of journal articles and the publications are steadily growing. The top 10 most productive countries were identified and China topped the list with highest citations (912) followed by India (860), UK (853) and USA (717). The prolific authors in e-waste management were Li j, Osibanjo O and Nnorom IC. The highly preferred journals for publications are Journal of Cleaner Production, Waste Management and Waste Management and Research.

Keywords: Bibliometric analysis, Biblioshiny, bibliometrix R package, E-Waste management, Scopus, Thematic map, Word growth,

1. Introduction

While searching the image for e-waste on internet we will get the, children picking scrapped electronics plucking bits of copper from circuit boards and plastic wire coverings, hauling cartloads of cathoderay tubes and computer monitors and other electronics, stoking the fires that melt plastic casings. Without gloves, without masks to filter particulates floating up from the burning and unseen dioxins emerging from the caldron.

E-waste is waste generated from any equipment running on electricity or a battery including computers, laptops, televisions, digital video disc players, mobile phones, and many

others household appliances to personal products such as cellular phones, consumer electronics, and computers which have been disposed by their original users. It has become a fastest growing environmental threats attributed to technological advancements, urbanization, industrialization, increasing population, and economic development. Since from the 1990s electronic waste (e-waste) has been recognized as the fastest-growing component of the solid-waste stream(Ogunseitan, Schoenung, Saphores, & Shapiro, 2009). In the absence of adequate recycling policies it may shorten the life span and they are discarding without much concern over the environment and public health.

In 2016 and 2017, approximately 45 and 46 million tons of electronic waste (e-waste) was generated globally. Amount of e-waste generated is likely to increase to 52.2 million tons by the year 2021(Miner, Rampedi, Ifegbesan, & Machete, 2020). Researchers suggested that with an annual growth rate of 4% to 5%, e-waste is becoming one of the fastest growing waste streams in the world. European countries generate approximately 8.3 to 9.1 million tons of e-waste per annum. Moreover, the generation rates of e-waste are expected to rise further because of the shorter life spans of some of the electronic products. Introducing more and more acts, policies, rules and awareness on e-waste will play a major role in making toxin free environment for future generation. In some countries dealing with e-waste is the primary responsibility of manufacturers of electrical and electronics goods.

2. Related literature

2.1 E-Waste Management

Faster technological evolution is the only cause for high use of electronic products and makes the product rapid but, the risk factor is managing e-waste for sustainability of environment (Dino Rimantho, Rimantho, Noor, Eriyatno, & Effendi, 2020).Several important information regarding the risk factors of the e-waste management process were collected using literature studies and interview methods and result shows that several highest Risk Priority Number such as manual technology (729), number of technologies (729), legal compliance (729), and recycling costs (729). Further concluded with risk evaluation in the e-waste management process is focused on the highest risk category(D. Rimantho, Rimantho, Noor, Eriyatno, & Effendi, 2020). A case study on recycling waste electrical and electronic equipment (WEEE) and the Management of its toxic substances in Taiwan showed that the average annual recycling of home electronic appliances, information technology products and lighting in Taiwan during the 2017–2018 were

around 117,000, 18,000 and 4500 metric tons, respectively but having the central governing authority, local governments, and private recyclers in Taiwan, the successful WEEE recycling system not only reduce the pressure on sanitary disposal systems, but also prevent the chemical hazards from solid waste incineration systems (Tsai, 2020). The use and consumption of mobile devices are increasing which inherently increases the generation of electronic waste (Pascuas-Rengifo, Beltran-Sanchez, & García-Quiroga, 2021). The study entitled psychometric properties of an instrument that measures adolescent attitudes towards electronic waste management was done with the objective to determine the psychometric properties of an instrument that measures adolescent attitudes towards the management of electronic waste and found that this scale could be applied in high school student populations and could be input for various works of research.

Further the studies were done on urban planning trends on e-waste management in Ghanaian cities (Asibey, King, Lykke, & Inkoom, 2021), knowledge, perceptions, and practices of electronic waste management among consumers in Kampala, Uganda and guided there is need for increased awareness on e-waste management to prevent its effects on health and the environment sensitization on e-waste handling practices before disposal and final disposal options available (Nuwematsiko et al., 2021). E-waste challenges in Cape Town and opportunity for the green economy studied by (Grant, 2019) Bangalore city require major infrastructural and administrative considerations on e-waste management initiatives (Borthakur & Govind, 2017), Nigeria has become a major receptacle for the developed world unwanted electronics and electrical equipment, accumulating cargo containers full of e-waste on a daily basis (Sullivan, 2014). Dealing with e-waste must remain the primary responsibility of manufacturers of electronic goods (Economic, Weekly, & May, 2012) and also the survey on household awareness and willingness to participate in e-waste management in Jos, Plateau State, Nigeria recommend educational interventions on sound e-waste management in the Jos metropolis, along with a systematic analysis on how policy interventions such as the producer responsibility schemes can be designed for effective e-waste management and recycling (Miner et al., 2020). The case study on Ghana done with an integrated assessment scheme for sustainable waste management of electrical and electronic equipment (Vaccari, Zambetti, Bates, Tudor, & Ambaye, 2020) and a Taiwan case study on recycling waste electrical and electronic equipment (WEEE) and the management of its toxic substances (Tsai, 2020).

2.2 Bibliometric and review study on e-waste management

Electronic waste (e-waste) has been widely studied by scholars all over the world, but the development trends in this field are few in bibliometric and literature review study which were found in the Scopus database. A bibliometric analysis on global trends and future prospects of e-waste research was done with the objectives to explore the status quo, hot topics, and future prospects in the field of e-waste from the Web of Science Core Collection and used Cite Space V, Histcite, and VOSviewer to analyze. A total of 2800 papers in e-waste research were identified, and the number of publications increased rapidly after 2004. Six thousand five hundred seventy-three authors participated in the e-waste research, but 70.01% of the authors published only 1 article. The most productive country in this field was China (1146 publications), and the most productive institution was the Chinese Academy of Sciences (370 publications). The Waste Management (225 publications) was the most productive journal, and Environment Science & Technology (9704 co-citations) was the most co-cited journal. The main hot topics in e-waste field were management and recycling of e-waste in developing countries, health risk, degradation and recovery of waste metal materials, and impact on children's health (Gao et al., 2019).

The findings after reviewing the literature from web of science on e-waste management in sub-Saharan Africa revealed that about 80% of research on e-waste management was undertaken in three countries: Ghana, Nigeria, and South Africa. The lack of policy and limited recycling infrastructure were the main barriers to effective e-waste management. The most of the countries in the region practice informal and rudimentary recycling methods and recommended to provide insight to policymakers (Maphosa & Maphosa, 2020) further, Several prominent theories and concepts within the boundary of waste management research require socio-cultural involvement for more seamless waste control, management, and treatment (Nguyen & Vuong, 2020).

3. Objectives of the study

The main objective of this study is to analyze the publications of global e-waste management research reported and indexed in the Scopus database and to present in tabular and diagrams. In particular, the study aims to find:

- Bibliometric profile of e-waste management research
- Documentwise distribution of publications
- Most cited publications in e-waste management
- Growth of the publications and average citations

- Most cited countries
- Author impact and source impact
- Collaborative network of documents published on e-waste management
- Frequently occurred author keywords with thematic map and word growth

4. Materials and Methods

A bibliometric method was used on the global e-waste management research publications indexed by Scopus database. The research data was retrieved on 26th April 2021 from the Scopus database using search string e waste management or electronic waste management or electrical waste management in article title field. The search strategy yielded 534 records, which was used for further analysis. All types of the publications were selected for the analysis. The complete bibliographic data was retrieved from Scopus database in .bib file format. Initially, the bibliometrix R package was installed and loaded through R Studio. Then, biblioshiny app was started by entering command biblioshiny () in R console.

The biblioshiny app for bibliometrix from R Statistical Package was used to carry out present bibliometric analysis. It has many features which are helpful to carry out indepth bibliometric analysis. It is an application that provides a webinterface for non-coders for bibliometrix tool. Finally, Scopus file in .bib format was uploaded on Biblioshiny interface. Further as per the objectives of the study, excel files and png files were downloaded and used for data analysis.

5. Results and Discussion

5.1 Main Information

The basic bibliometric information on E Waste Management retrieved from biblioshiny application is shown in the Table 1. Five hundred thirty four (n-534) documents were found from 309 sources with the time span from 1980 to 2021. Average citations per document is 14.09 and average citations per year per document is 1.9. Total author's keywords are 1080 and total references are 18383 for the retrieved documents. Type of documents includes 301 journal articles followed by 107 conference papers, 59 reviews and 40 book chapters. Authors of single-authored documents are 85 and Authors of multi-authored documents 1295.

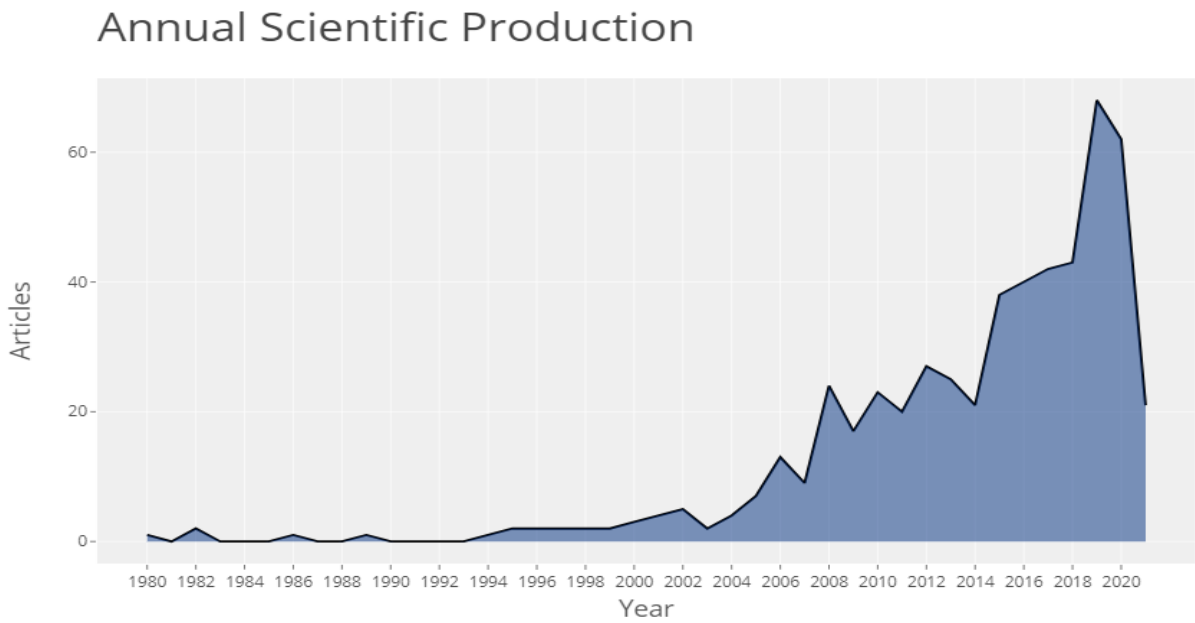
Table 1: Main Information About Data On E Waste Management	
Description	Results
Timespan	1980:2021
Sources (Journals, Books, etc)	309
Documents	534
Average years from publication	6.95
Average citations per documents	14.09
Average citations per year per doc	1.926
References	18383
DOCUMENT TYPES	
Abstract Report	1
Article	301
Book	5
Book Chapter	40
Conference Paper	107
Data Paper	1
Editorial	6
Erratum	4
Letter	3
Note	5
Review	59
Short Survey	2
DOCUMENT CONTENTS	
Keywords Plus (ID)	2515
Author's Keywords (DE)	1080
AUTHORS	
Authors	1380
Authors of single-authored documents	85
Authors of multi-authored documents	1295

5.2 Growth of Publications

Growth of Documents on e-waste management is shown table 2 and fig 1. There is increasing trend in the number of documents. During the first decade (1980 to 1990) only is 5 documents are published followed by 14 documents in second decade (1991 to 2000). It is clear from the numbers of documents (n=108) published from 2001 to 2010 that the real research on e-waste management started from the year 2001 and the concept of e waste management became serious on health and environment along with the electronic production. Further, it is seen that research and publication of documents (n=407) in the preceding decade (2011 to 2021) has gained momentous in the field of e waste management

Table 2: Growth of Publications	
Year	Documents
1980 to 1990	5
1991 to 2000	14
2001 to 2010	108
2011 to 2021	407
Total	534

Fig 1: Annual Scientific Production



5.3 Source Impact

Table 3: Prolific Sources in e-waste management						
Source	h_index	g_index	m_index	TC	NP	PY_start
Journal Of Cleaner Production	11	18	1.1	423	18	2012
Waste Management	10	17	0.7	1384	17	2008
Waste Management And Research	10	16	0.6	509	16	2006
Resources, Conservation And Recycling	11	14	0.7	1030	14	2008
Engenharia Sanitaria E Ambiental	4	7	0.2	54	13	2006
Environmental Science And Pollution Research	8	11	0.6	157	11	2009

Journal Of Material Cycles And Waste Management	7	10	0.4	355	10	2005
Handbook Of Electronic Waste Management: International Best Practices And Case Studies	3	3	1	19	9	2019
Electronic Waste Management And Treatment Technology	3	5	1	33	8	2019
Sustainability (Switzerland)	6	8	1	99	8	2016

Table 3 presents the top 10 journals preferred by the researcher's on e-waste management field. The Journal of cleaner production found to be most preferred journal by the researcher with 18 publications across the world. The journal entitled Waste Management was found to be highly cited with 1384 citations followed by Resources, Conservation and Recycling with 1030 citations during the reported period. The Journal of cleaner production ranked first in its h-index (11), m-index (1.1) and g-index (18) values. It is notable that the newly introduced journals also positioned in top ten journals.

5.4 Most cited publications in e-waste management literature indexed in the Scopus database

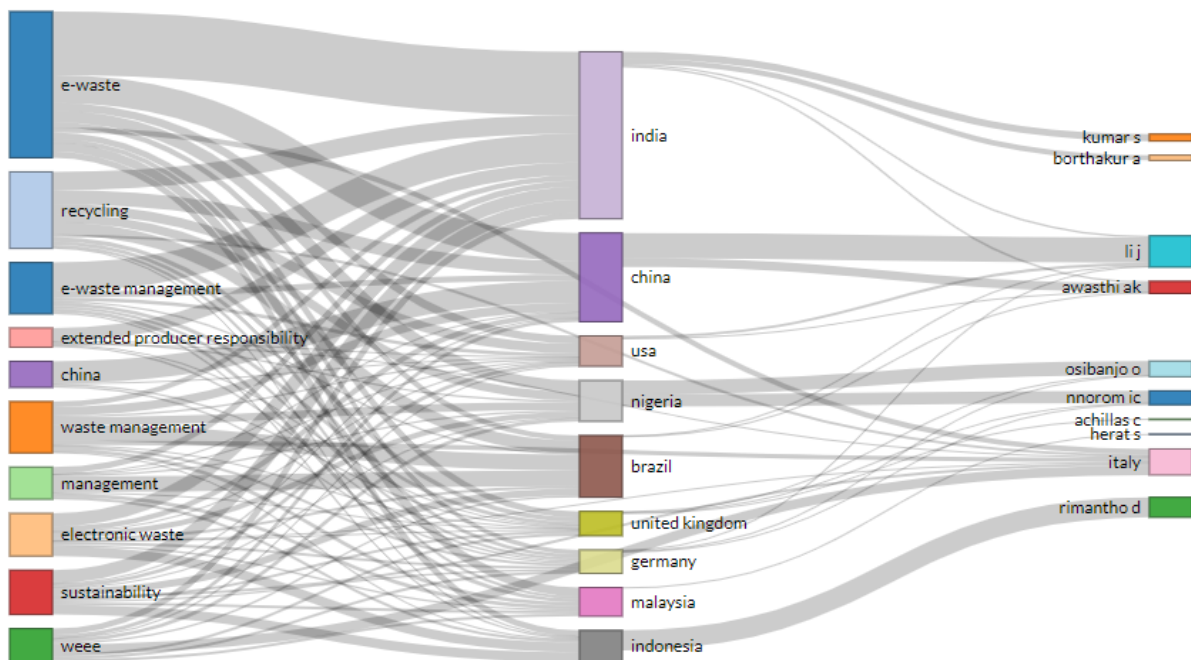
Table 4: Most cited documents in the e-waste management literature indexed in the Scopus database		
Title	Year	Cited by
How are WEEE doing? A global review of the management of electrical and electronic wastes	2011	538
Electronic waste management approaches: An overview	2013	347
Overview of electronic waste (e-waste) management practices and legislations, and their poor applications in the developing countries	2008	325
Exploring e-waste management systems in the United States	2008	241
Reverse supply chain management and electronic waste recycling: A multitiered network equilibrium framework for e-cycling	2005	223
Producer responsibility for e-waste management: Key issues for consideration - Learning from the Swiss experience	2009	185
Characterisation of polymer fractions from waste electrical and electronic equipment (WEEE) and implications for waste management	2007	175
The challenge of electronic waste (e-waste) management in developing countries	2007	164
Electrical and electronic waste management in China: Progress and the barriers to overcome	2006	155
Management and recycling of electronic waste	2013	145

The document entitled “*How are WEEE doing? A global review of the management of electrical and electronic wastes*” published in the year 2011 is the most cited (538) document followed by *Electronic waste management approaches: An overview* published in the year 2013 with 347 citations, *Overview of electronic waste (e-waste) management practices and legislations, and their poor applications in the developing countries* published in 2008 with 325 citations, *Exploring e-waste management systems in the United States* published in 2008 with 241 citations and *Reverse supply chain management and electronic waste recycling: A multitiered network equilibrium framework for e-cycling* with 223 citations and remaining are the below hundred citations seen in above table 4.

5.5 The three field plot of top ten Authors, Countries and Keywords Relations

The relations between the top ten authors, Countries and keyword were visualized using the Three Fields Plot. Here the relevant elements were represented in the diagram by rectangles with a different colors. The height of the rectangles depended on the value of the sum of the relations arising between the element that the rectangle represents (one of the elements in the authors, countries and keyword) The more relations element had the higher rectangle representing it. The figure 2 shows that India having the strong relationship with e-waste keyword followed by China and USA. The keyword e-waste has the strong relation with all top ten countries followed by recycling, e-waste management, electronic waste and sustainability.

Fig 2: Three field plot of top ten Authors, Countries and Keywords Relations



5.6 Most Cited Countries

Table 5 shows the most productive countries in terms of citations on e-waste management. The China topped the list with highest citations (912). The other productive countries were India with 860 citations followed by United Kingdom with 853 citations and USA with 717 citations. Germany with 222 citation in 9th position and Malaysia with 219 citations ranked 10th position.

Country	Total Citations	Average Article Citations
China	912	21.714
India	860	11.316
United Kingdom	853	56.867
USA	717	47.8
Nigeria	709	78.778
Australia	440	55
Brazil	354	8.233
Japan	242	34.571
Germany	222	27.75
Malaysia	219	12.167

5.7 Author Impact

Author	h_index	g_index	m_index	TC	NP	PY_start
Li J	9	15	0.563	585	15	2006
Osibanjo O	7	8	0.467	707	8	2007
NnoromIc	6	7	0.4	699	7	2007
AwasthiAk	4	4	0.667	136	4	2016
Kim J	4	4	0.286	292	4	2008
Zeng X	4	4	0.444	273	4	2013
Herat S	3	6	0.2	73	6	2007
Kumar S	3	6	0.167	78	6	2004
Borthakur A	3	5	0.333	49	5	2013
Achillas C	3	4	0.273	41	4	2011

The performance of top ten productive authors on the basis their publications, citations and h-index are shown in table 6. These authors together contributed 63 papers with 11.79% share in the cumulative publications output of World with 2933 citations during the reported period. The publication count reveled Li J with 15 publications ranked first in the list. Osibanjo O has scored the highest number of citations (707) and h-index (7)for his 8 publications. The highest g-index value was contributed by Li J (15) and Osibanjo O (8) shown in Table 6.

5.8 Most Frequent Authors Keywords

Table 7 and fig 3 proves that e-waste is the top most used keyword used by the authors that is 144 times in due course of time followed by recycling 70 times occurred, e-waste management 54 times, waste management 47 times, electronics waste by 44 times Weee (Waste from electrical and electronic equipment) 43 times and so on. In figure 3 bigger the size of keyword shows the highest number of occurrence and vice versa.

Further, the dynamic of the time-dependent occurrence of author keywords was investigated and shown in fig 4. It could be seen that the number of all main-term occurrences per year increased over time, but some of them grew more dynamically than others. The terms with the highest increase in occurrences over time were electronic waste, waste management, recycling, wastes, waste disposal, electronic equipment and sustainable development

Table 7: Top 10 Author Keywords with their Frequencies	
Words	Occurrences
e-waste	144
recycling	70
e-waste management	54
waste management	47
electronic waste	44
Weee (Waste from electrical and electronic equipment)	43
management	30
sustainability	28
extended producer responsibility	18
china	17

Fig 3: Word Cloud (Author's Keywords)



Fig 4: Word Growth

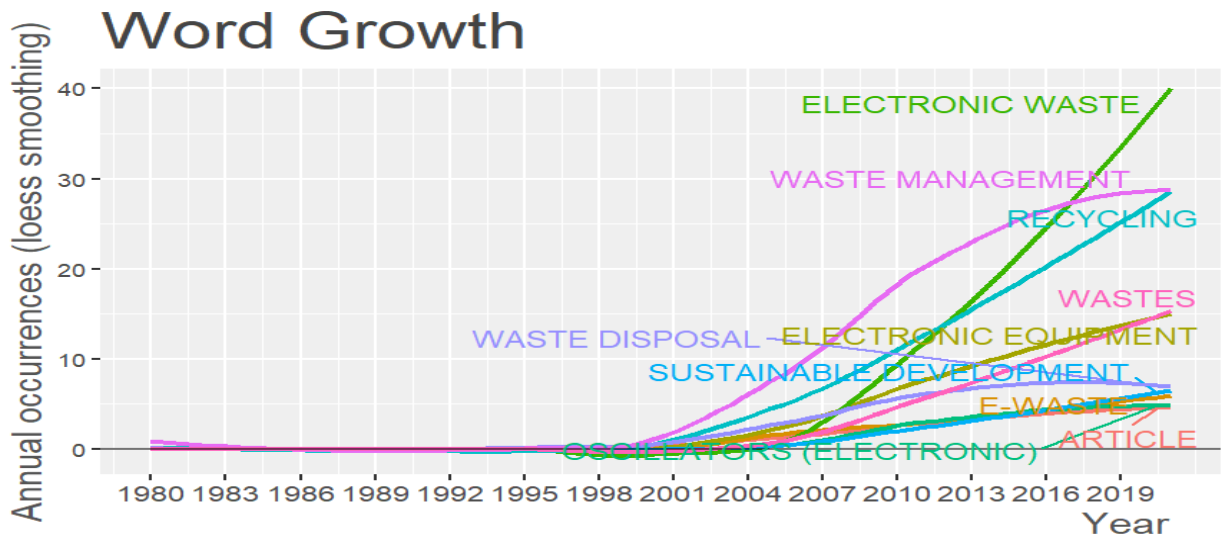


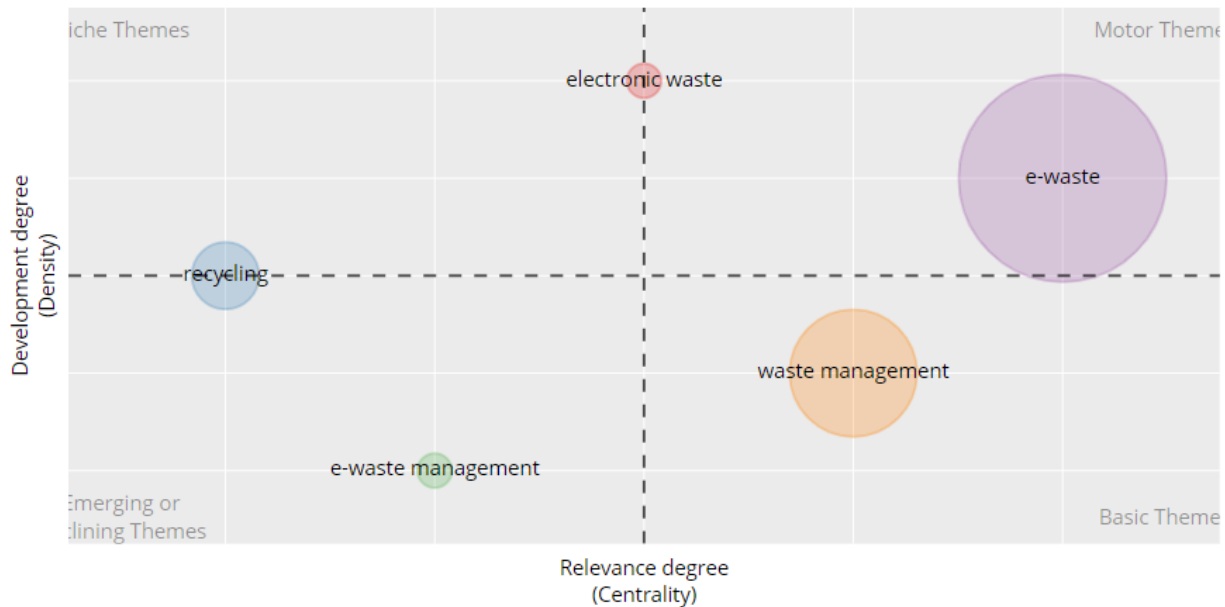
Fig 5: Collaborative network of documents published on e-waste management



Collaborative network of documents published on e-waste management shown in fig 5 in which we find four colored cluster. Blue colored cluster network includes India, Srilanka and Korea, red colored network includes UK, Germany, China and USA, purple includes Zimbabwe, Nigeria and South Africa and green cluster includes Romania, Italy, France, Brazil and Australia.

Clusters of keywords considered as themes, whose density and centrality can be used in classifying themes and mapping in a two-dimensional diagram. Fig 6, thematic map analyzes themes according to the quadrant in which they are placed firstly upper-right quadrant: motor-themes secondly lower-right quadrant: basic themes thirdly lower-left quadrant: emerging or disappearing themes and fourth upper-left quadrant: very specialized/niche themes.

Fig 6: Thematic Map: e-waste management



6. Conclusions

The present study analyzed the global e-waste management research output published during 1980 to 2021. It is observed that the publications are steadily growing up. The study found journals are the preferred form for the research publications on e-waste management. China topped the list with highest citations (912) followed by India (860), UK (853) and USA (717). The prolific authors in e-waste management were Li j, Osibanjo O and Nnorom IC. The highly preferred journals for publications are Journal of Cleaner Production, Waste Management and Waste Management and Research. The top authors keywords are e-waste with 144 times, followed by recycling 70 times occurrence, e-waste management 54 times waste management by 47 times electronics waste by 44 times Weee (Waste from electrical and electronic equipment) 43 times and so on. The documents covered given more focus on the e-waste management, recycling, health awareness. Further enforced for introducing varies policies, acts, rules on e-waste management

and urged for managing with e-waste should be made the primary responsibility of manufacturers of electrical and electronics goods.

7. Further studies

Further in depth Bibliometric analysis and reviews can be done on the e-waste management effects on health and environment. Action taken by various countries on recycling and major reasons for increasing e-waste globally.

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