

# Characterization of top-100 researches on e-waste based on bibliometric analysis

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## Research Article

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# Abstract

**Objectives:** With rapid development of energy, information and communication technology, e-waste problem has become one of the global issues to be settled urgently. The main features on publication years, journals, countries and institutions, authors, keywords, content types of the 100 most-cited articles on e-waste had been unfolded in this research.

**Methods:** Bibliometric analysis method was applied to analyze various attributes on the 100 most-cited articles which were retrieved from WoSCC on May 25, 2020 by utilizing the software tools Microsoft Excel 2016 and VOS viewer 1.6.9.

**Results:** The publication year and citation number of the 100 articles ranged between 2008 and 2017 and from 87 to 804, respectively. *Environmental Science & Technology* ( $n = 18$ ) published the maximum articles. *Waste Management*, *Journal of Hazardous Materials*, *Environmental Science & Technology* could be considered to be the core journals on the study field of e-waste due to their comprehensive high ranks based on various dimensions. Among all related countries and institutions, the USA and Chinese Academy of Sciences published the maximum articles. The related countries and institutions conducted intimate collaborations. The maximum articles were published by the author Mai Bi xian. The two authors Mai Bi xian and Chen She jun could be considered to be the most significant researchers on e-waste, because compared with other authors, the two authors published the maximum articles and possessed the maximum citations. 255 keywords were totally acquired among the 100 articles, and the keywords "e-waste" and "recycling" held the highest occurrences. The main hot study themes are environment and health, management and economic, technique and processing, characteristic and property.

**Discussion and conclusion:** Overall completeness and applicability of the evidence found in this study were verified sufficiently, the potential biases in the review process were also considered. This study was compared with other studies or reviews related e-waste, and the implication for practice and research of this study were explained as well. The current types of study on e-waste mainly contain the influence of e-waste on health and environment, and the management and economic of e-waste. The further research can expand and deepen themes such as characteristic and property, technique and processing on e-waste.

## 1. Background

Nowadays, with electric and semiconductor technologies making a tremendous advancement compared with twenty years ago which made the consumer demand for electrical energy and information devices grow at an incredible speed, the global countries and districts are being urgent to resolve the tough problem of e-waste. (Ongondo et al. 2013)

Electrical and Electronic Equipment (EEE) is usually defined as items or wares which are made with electrical or electronic parts. E-waste is defined as the EEEs which have been abandoned as waste or rubbish without reusing( Wath Sushant B et al. 2011; Sajid Muhammad et al 2019). E-waste has different

appellations under different conditions such as electronic waste, e-scrap or Waste Electrical and Electronic Equipment (WEEE) (Li Jinhui et al. 2015; Alghazo Jaafar et al. 2019; Ceballos Diana M et al. 2015).

E-waste is involving in more and more applications. Besides everyday household, business use, EEEs are applied widely in household and business use, as well as transportation (Yun Liu et al. 2018; Andersson Magnus et al. 2019), health care (Matthew Toews et al. 2018; Thelen Sebastian et al. 2014), and generation and conversion of energy (Jie Tian et al. 2018; Nan Zhao et al. 2019). In recent years, the application of e-waste is gradually expanded to traditional wares, for instance clothes, skin care and furniture (M. Virili et al. 2014; Menglong Li et al. 2019). With rapid progress of communication and information technology, EEEs are increasingly equipped within the devices of the Internet of Things (IoT) (Zhao Jindong, Yue Xingzuo. 2020), artificial intelligence (AI) (Wang Xiangming et al. 2018) etc.

According to The Global E-waste Monitor 2020, almost 53.6 million Mt of e-waste (excluding PV panels) emerged, or 7.3 kg per capita in 2019, while 44.4 Mt, 6.4 kg per capita in 2014. It means that the increment of the global generation of e-waste was up to 9.2 Mt from 2014 to 2019. Predictably, the amount of e-waste generated will exceed 74Mt in 2030, nearly doubling in only 16 years. The global e-waste is increasing at a striking speed of about 2 Mt per year (Vanessa Forti et al. 2020).

Each E-waste ware is different in many ways, such as materials, the disposing and recycling means and harm to the human and environment if not processed soundly. Even worse, some E-waste may comprise several toxic substances or hazardous materials, for instance, mercury (Lim Seong-Rin, Schoenung Julie M. 2010), brominated flame retardants (BFR) (Muenhor Dudsaddee, et al. 2010), etc. The current situation is bound to cause tremendous risks to the human and environment which includes the high amount of e-waste, low rates of collection, and non-environmentally proper management. Moreover, improper management of e-waste contributes to global warming (Waeger P.A, et al.). Actually, E-waste is of great values, because the useful and precious parts within it completely can be utilized as secondary components or materials as long as e-waste is processed and recycled by proper means (Das A et al. 2009).

Researchers from different regions and countries have implemented a variety of studies, in the progress of researching e-waste, such as environment conditions at e-waste recycling site (Wang Yan et al. 2012; Zhang Quan et al. 2014; Huang Honglin et al. 2011; Ha Nguyen Ngoc et al. 2009), the influences on of e-waste human (Zheng Xiaobo et al. 2015; Zheng Liangkai et al. 2008; Zheng Jing et al. 2013; Chen Aimin et al. 2011), the public management on e-waste (Yin Jianfeng et al. 2014; Tanskanen Pia et al. 2013; Afroz Rafia et al. 2013; Yu Jinglei et al. 2010), the processing and recycling technique of e-waste (Akcil Ata et al. 215; Zhang Lingen et al. 2016; Cui Jirang et al. 2008; Joshi Deepak et al. 2012). However, as so far there are few studies to study the present situation and predict the tendency of researching e-waste using bibliometric analysis method.

Bibliometric analysis method is usually utilized as a statistical and quantitative analysis tool of study publications which can extract measurable data and collect valuable knowledge from a publication (Gao

Ya et al. 2019; Lu Cuncun et al. 2019; Lu Cuncun et al. 2019; Shi Shuzhen et al. 2020; Liu Ming et al. 2020). It has been applied in various study fields to discover the current situation, the key topics and the tendency in study works, because this method can well evaluate the literature traits of specific research subject and the influence of study publications by assessing countries and institutions, journals, authors, and keywords of specific publication (Ya Gao et al. 2019).

The research implemented a bibliometric analysis on the 100 most-cited articles of e-waste aiming at analyzing the distribution of publication year, countries and institutions, journals, keywords, authors, numbers of citations, and other feature, identifying the collaboration among countries and institutions, discovering the current hot themes and future trends on e-waste study. All the members in our team expect that efforts in studying the 100 highly cited articles can provide some valuable information for enhancing global public knowledge on e-waste, decelerating the speed of e-waste generation, diminishing the global amount of e-waste every year, elevating the management level of e-waste and advancing the technology of processing and recycling e-waste.

## 2. Methods

### 2.1 Data source and search strategy

The research implemented an overall retrieval in SCI-E of WoSCC on May 25, 2020. The retrieval was accomplished within the day to eliminate deviation led by the daily updates of the database. Retrieval method was as shown below: TS=( "electrical waste" OR "electrical wastes" OR "electronic waste" OR "electronic wastes" OR "e-waste" OR "waste electrical" OR "wastes electrical" OR "waste electronic" OR "wastes electronic" OR "electronic rubbish" OR "electronic garage" OR "electrical rubbish" OR "electrical garage" OR "waste electrical and electronic equipment" ). The screening procedure was as follows. The first step was that the research team set the sequence of the results based on the "citation frequency" from high to low without time and language restrictions, but with the publication types restricted to "article" and "review". Secondly, two independent reviewers filtered out the 100 most-cited results most related to e-waste. In order to reach agreement, both of them discussed disagreements carefully. To extract the relevant literature traits of the 100 articles such as title, publication years, journals, institutions and countries, authors, citations, keywords and so on, the research team exported the citation report and the marked-results spreadsheet of those articles from SCI-E database, and took advantage of them fully.

### 2.2 Bibliometric analysis

The relevant traits of publication year, journals and type of study content were extracted by utilizing Microsoft excel 2016 (Shuzhen Shi et al. 2020). It was also applied to generate evidence graphs. The evidence of relevant traits could be presented well by evidence graphing which included the bubble graph and the histogram in this research. Two types of bubble graphs were generated to demonstrate: (1) the distribution of articles and citations by year (bubble size: the average quantity of citations; number on the bubble: the quantity of articles in the specific year; Y-axis: the total quantity of citations; X-axis:

publication year); (2) the average quantity of citations of articles sorted by types of study content (bubble size: the quantity of articles of specific type; Y-axis: the average quantity of citations; X-axis: different types of study content;). The histogram was used to demonstrate the distribution of different types of study content (the anterior Y-axis: the quantity of articles; the rear Y-axis: the percentage of citations; X-axis: types of study contents;).

The network maps of countries and authors and the density map of keywords were generated by utilizing VOS viewer 1.6.9 (Leiden University, Leiden, Netherlands). The data in the citation report and the marked-results spreadsheet were normalized before importing in VOS viewer to generate maps. For instance, the normalization of keywords was that various expressions of the same keyword were requisite to employ a uniform expression to eliminate deviation, which was completed artificially by the authors. With respect to the national information identified by the tool, Northern Ireland, unified Wales, England and Scotland were classified into the UK, Hong Kong, Macao, and Taiwan were classified into China. The explanation of maps generated by VOS viewer should take into consideration three properties: colors, size, and distance. In the maps, the nodes were interpreted as specific items which stand for countries, authors, or keywords, and the size of them were interpreted as the quantity of articles or occurrences, and the length of the links between them were interpreted as the affinity of their relationship.

Based on the data of the World Bank, the research sorted countries into developing or developed countries. 2019 Journal Citation Reports provided the newest IFs of the related journals.

### 3. Results

3507 articles in total were acquired by the primary search which were then ranked by citation frequency. We distinguished 100 studies which are the most relevant to the study theme of e-waste, also were all published in English language. Citation frequency of all the 100 articles ranges from the lowest 87 to the highest 804. The total quantity of citations was 147,43, and the average quantity of citations of the 100 articles was 147.43. The 100 most-cited articles have been presented in Appendix 1.

#### 3.1 The distribution of articles and citations by year

The 100 most-cited articles were published between the year of 2008 and 2017. **Figure 1** below mainly represents the citation distribution by publication year in which the bubble size is denoted as the average quantity of citations, numbers marked on the bubble are denoted as the quantity of articles issued in the corresponding year, Y-axis is denoted as the total quantity of citations and X-axis is denoted as the publication year. The anterior number of the number label beside the bubble is the total quantity of citations, and the rear is the average quantity of citations in the specific publication year. As seen easily in the **Fig.1**, it was in the publication year of 2009 that the total quantity of citations was the highest ( $n=3286$ ), and in the publication year of 2017 that the total quantity of citations was the lowest ( $n=108$ ). With respect to the average quantity of citations, the biggest was 275 in 2008, and the smallest was 106 in 2016, represented by the biggest and smallest bubbles, respectively. Across the 10 publication years

from 2008 to 2017, the largest number of articles was issued in 2009 which was up to 19 articles, followed by 2011 with 16 articles, 2010 and 2013 with 12 articles, respectively, and only 6 in 2016, 4 in 2017.

## 3.2 Journals

The top 100 cited articles were entirely issued by 25 journals which are all owned by four countries, the USA, the England, Netherlands and Germany. all journals were represented in the **Table 1**. Among the 25 journals, eleven journals were managed by the USA, accounting for up to 44%, followed by England with 9 journals, accounting for 36%.

The impact factors of all published journals ranged from the highest 26.416 to the lowest 1.192. The *Materials Today* held the highest impact factor ( $IF = 26.416$ ), but only issued one article, and The *Annals of Global Health* with the lowest impact factor ( $IF = 1.192$ ) also only published just one article. The IFs of three journals were higher than 10, which were The *Materials Today*, the *Lancet Global Health* and the *Renewable & Sustainable Energy Reviews*, and their numbers of articles were all just 1 or 2, and their ratio of total citations reached 4.78%. However, it was with a much lower impact factor that the four journals all contributed more than ten articles, which are The *Environmental Science & Technology*, The *Waste Management*, the *Journal of Hazardous Materials* and the *Environment International*. Except for the four journals, the number of articles of other journals were all less than 10.

The citation numbers of these journals ranged from the highest 2517 to the lowest 88 in which three journals' were more than 2000. To be specific, the *Journal of Hazardous Materials* with 2517, the *Waste Management* with 2370, the *Environmental Science & Technology* with 2056, respectively. The three journals' ratio of total citations were up to about 50%, although they had a relatively low impact factors.

Based on the analysis of the article and citation number of these journals, we can conclude that the article and citation number of the three journals were both top 3 among studied 100 articles, which reflected their substantial position in the e-waste field. Consequently, the three journals, *Waste Management*, *Journal of Hazardous Materials*, *Environmental Science & Technology* can be considered to be the core journals in the study field of e-waste. By analyzing the impact factor of these journals, we can also conclude that the article and citation number of one journal don't have an absolute relationship with its impact factor.

Table.1 Journals published the 100 most-cited articles on e-waste

Journals	Quantity	Citation	Countries	IFs(2019)
	(%)	quantity		
Environmental Science & Technology	18	2056	USA	7.864
Waste Management	14	2370	USA	5.448
Journal of Hazardous Materials	12	2517	Netherlands	9.038
Environment International	10	1128	USA	7.577
Science of The Total Environment	9	1750	Netherlands	6.551
Environmental Pollution	6	666	England	6.792
Journal of Cleaner Production	5	653	USA	7.246
Chemosphere	4	483	England	5.778
Resources Conservation and Recycling	4	452	Netherlands	8.086
Renewable & Sustainable Energy Reviews	2	325	USA	12.11
Journal of Environmental Management	2	255	England	5.647
Minerals Engineering	1	333	England	3.795
Materials Today	1	202	England	26.416
Journal of Industrial Ecology	1	190	USA	6.539
Environmental Research	1	182	USA	5.715
Lancet Global Health	1	179	England	21.597
International Journal of Advanced Manufacturing Technology	1	141	England	2.633
Environmental Health Perspectives	1	132	USA	8.38
Annals of Global Health	1	113	England	1.192
International Journal of Production Economics	1	112	Netherlands	5.134
Acta Materialia	1	111	USA	7.656
Proceedings of The National Academy of Sciences of The United States of America	1	108	USA	9.412
Ecotoxicology and Environmental Safety	1	108	England	4.872
Management Science	1	89	USA	3.935
International Journal of Hygiene and Environmental Health	1	88	Germany	4.801

### 3.3 Country and institution

25 countries in total took participation in the issue of the 100 articles. Developed countries were the majority of them. However, China contributed maximum articles ( $n=61$ ) which is developing country, followed by USA ( $n=17$ ), while Australia, India, Switzerland were ranked in the third place with 10 publications. The rest of 20 countries all contributed to less than 6 articles. Regrettably, only two in the top 10 countries belonged to developing countries. **Figure 2** represents the collaboration of the countries that issued the 100 articles which showed that China, Switzerland and Netherlands maintained intimate cooperation with other countries.

28 institutions in total were found to publish two or more articles, among them two institutions took participation in the publication of more than ten articles. The highest quantity of publications was possessed by the Chinese academy of sciences, which was up to 27 articles, followed by Tsinghua university with 11 articles. **Table 2** represents the top 10 countries and institutions that published the 100 articles. To be surprised, the top 7 institutions came from China altogether.

Table 2 The top 10 countries and institutions published the 100 articles on e-waste

Rank	Countries	Quantity	Citations
1	China	61	7730
2	USA	17	1893
3	Australia	6	1029
4	India	6	825
5	Switzerland	6	878
6	England	5	1024
7	Germany	5	593
8	Belgium	4	472
9	Japan	4	523
10	Netherlands	4	475
Rank	Institution	Number	Citations
1	Chinese Academy of Sciences (China)	27	3451
2	Tsinghua University (China)	11	1168
3	Hong Kong Baptist University (China)	6	847
4	Sun Yat-sen University (China)	6	801
5	Shanghai Jiao Tong University (China)	5	816
6	Shantou University (China)	5	635
7	City University of Hong Kong (China)	3	357
8	Delft University of Technology(Netherlands)	3	296
9	Empa(Switzerland)	3	445
10	Minist Environm Protect(China)	3	323

### 3.4 Author

A total of 382 authors were involved in the issue of the 100 articles. And 60 ones contributed two or more articles. The author Mai bi xian took part in publishing eleven articles, and could be considered as the most productive. There were three authors of whom the number of contributed articles were more than ten, they were Mai bi xian with 11 articles, Chen She jun with 10 articles and Luo Xiaojun with 10 articles. From **Table 3**, it can be found that the three authors not only had the top three number of contributed

articles in the top cited 100 articles, but also the top three number of citations which were 1458, 1361 and 1350, respectively. The number of articles and citations of all other authors were below ten and one thousand.

Table 3 Top 10 productive authors

Author	Articles	Citations
Mai Bi Xian	11	1,458
Chen She Jun	10	1,361
Luo Xiao Jun	10	1,350
Li Jin Hui	8	833
Wu Jiang Ping	5	782
Yang, Zhong Yi	5	714
Huo Xia	5	635
Luo Yong	4	700
Xu Zhen Ming	4	681
Li Yan	4	503

### 3.5 Keywords

A total of 255 keywords were collected from the top cited 100 articles which had a total frequency of 393. Among all the keywords, the frequency of occurrence of the keyword “e-waste” was the highest ( $n = 33$ ), the keywords “recycling” ( $n=17$ ) and “electronic waste” ( $n=8$ ) were with the second and third highest frequency of occurrence. The 19 keywords listed in **Table 4** were all with 3 or more occurrences, part of the **Table 4** were about e-waste, electronic waste, waste electrical and electronic equipment, weee; part of it were associated with environment and health, such as recycling, soil, human exposure, some of it were about chemicals, for instance, heavy metal, metal recovery, PBDES, leaching, pahs, pcbs, polybrominated diphenyl ethers (pbdes), some of it were related to management and district, such as china, south china, extended producer responsibility, risk assessment. **Figure 4** is a density map of keywords in which the hot spot with red or yellow color stands for high occurrence, and the spot with green or blue color stand for low occurrence. According to this rule, we can easily find that the red spot included the keywords e-waste and recycling, which have the highest frequency of occurrence, the yellow ones consists of 10 keywords, mainly about electronic waste, soil, weee, pbdes, extended producer responsibility, waste electrical and electronic equipment , resource utilization, metal recovery, china, cadmium, which have a relatively high

frequency of occurrence, meanwhile the green and blue ones includes weee management, leaching, epr, incineration, pcdd/fs, pahs, pcbs, south, air, dust etc, which are of much low frequency of occurrence.

Table 4 keywords of occurrence with 3 and more times

Keyword	N(%)
e-waste	33(8.40%)
recycling	17(5.15%)
electronic waste	8(2.04%)
soil	7(1.78%)
weee	7(1.78%)
heavy metal	5(1.27%)
heavy metals	5(1.27%)
metal recovery	5(1.27%)
PBDES	5(1.27%)
waste electrical and electronic equipment (weee)	5(1.27%)
china	4(1.02%)
human exposure	4(1.02%)
extended producer responsibility	3(0.76%)
leaching	3(0.76%)
pahs	3(0.76%)
pcbs	3(0.76%)
polybrominated diphenyl ethers (pbdes)	3(0.76%)
risk assessment	3(0.76%)
south china	3(0.76%)

### 3.6 Types of study content

The top cited 100 articles could be classified into four types according to the study content. The four types of the study contents contain characteristic and property, environment and health, management and economic, technique and processing. The four types were much different in its number of articles.

Specifically, as seen in the **Figure 5**, there were 3 articles about the characteristic-and-property type, 49 articles related to the environment-and-health type, 27 articles associated with the management-and-economic type and 21 articles concerning the technique-and-processing type. Obviously, the environment-and-health type held the highest quantity of articles, and the characteristic-and-property type with the lowest quantity of articles. The two other types of study content are very close in quantity of articles. The total quantity of citations and the percentage of citations of each type rank as same as its quantity of articles, which is also demonstrated in the figure.

However, the average quantity of citations of each type have different features from the former two indexes. Actually, as seen in the **Figure 6**, the environment-and-health type possessed the lower average quantity of citations with 126.94, and the technique-and-processing type owned the highest average quantity of citations with 179.52. The average quantity of citations of characteristic-and-property and environment-and-health types is below 150, the management-and-economic and technique-and-processing with above 150.

## 4. Discussion

### 4.1 Summary of the main results

This research synthetically analyzed the 100 most-cited articles on e-waste in terms of publication years, journals, countries and institutions, authors, keywords, and study contents. The main study results are as below: 1. The publication year of the 100 articles were distributed from 2008 to 2017, both the biggest total quantity of citations and the biggest quantity of articles were in the publication year of 2009, the biggest average number of citations were in 2008. 2. The 100 articles were published by 25 journals with impact factors from 26.416 to 1.192. The three journals, *Journal of Hazardous Materials* ( $IF=7.65$ ), *Waste Management* ( $IF = 5.431$ ) and *Environmental Science & Technology* ( $IF = 7.149$ ) are the core journals on e-waste. 3. 28 institutions and 25 countries in total took part in publishing the 100 articles. China and its institutions are most influential in this field with biggest number of article and citations. 4. 382 authors contributed to the 100 articles in total, and Mai Bi xian and Chen She jun were the most important experts in this field. 5. A total of 255 keywords were acquired in the 100 articles, and the keywords "e-waste" and "recycling" held the highest occurrences. 6. Through analyzing its study content comprehensively, the study content of the 100 articles could be classified into four types including the characteristic-and-property type, the environment-and-health type, the management-and-economic type, the technique-and-processing type. The environment-and-health type was with the most number of articles and biggest percentage of citations, while the characteristic-and-property type with the least.

### 4.2 Completeness and applicability of the evidence

The evidence mainly described above found by the study in this paper are of great completeness and applicability.

The completeness of the evidence could be mainly justified by data resource, search strategy and the method. The SCI-E of the WoSCC from which the studied 100 articles were selected is a global citation database in which more than 9200 of the most influential journals across 178 scientific disciplines are indexed now. Because the database is publisher-independent and has the robust evaluation and curation of its data, it is most worth being trusted.

The search strategies were specially designed to guarantee the retrieved articles were the most professional, valuable, and influential. The cooperation and devotion of all the members in the study team ensured the analyzed material and the attained evidences were relevant and accurate. The software tools applied in this study also made a significant contribution to the integrity of the study.

Known as an useful and effective method, the method of bibliometric analysis were utilized in various study fields, such as computer and information science (Bonilla Claudio A et al. 2015; Cancino Christian et al. 2017; Heradio Ruben et al. 2016; Bornmann Lutz et al. 2015), library science (Bonilla Claudio A et al. 2015; Bornmann Lutz et al. 2015), construction and building technology (Santos Ruben et al. 2017), urban studies (Mora Luca et al. 2017), business and economics (Rey-Marti Andrea et al. 2016), automation and control systems (Liu Weishu et al. 2017), green and sustainable science (Ruhanen Lisa et al. 2015), manufacturing and engineering (Fahimnia Behnam et al. 2015), and achieved plenty of significant study results, which provided an excellent guide and reference for this study.

The applicability of the evidence can be expected in many ways. The materials and evidences in this study can enhance the awareness (Afroz Rafia et al. 2013; Borthakur Anwesha et al. 2017) of people, organizations and nations all around the world on management and recycling of e-waste, and provide grounds for officers in formulating policies and laws on e-waste. (Pariatamby Agamuthu et al. 2013; Daum Kurt et al. 2017; Gok Gulden et al. 2017).

The evidences are especially meaningful for the researches on e-waste in the future. The succeeding researches can seek the causes hidden under the evidences, for instance, find an overall explanation to the question “why the most articles were published int the year of 2009”, “why China could be the center of researching on e-waste” and so on. (Davis John-Michael et al. 2019; Laser Stefan 2016; Breivik Knut et al. 2016). The researchers can strengthen the studies on the characteristic and properties of e-waste based on the result that the characteristic-and-property type of study contents possessed the least number of articles and the lowest percentage of citations, and discover the new study contents on e-waste except for the four types found in this study (Ya Gao et al. 2019; Filippo Corsini et al. 2012).

According to the core journals found in this study, the researchers could find the newest and valuable studies on e-waste more quickly, and issue their own study results in proper journal (Solarino Stefano 2012; Maria Teresa San-Miguel et al. 2011; Black Nick, Davies Sally C 1999). In addition, based on the core countries, institutions and experts found in this study, the researchers in the study field of e-waste

could develop and explore elaboration more efficiently with global partners. (Buse K et al. 1998; Osterblom Henrik et al. 2012; Wagner Caroline S et al. 2015)

The evidences are also useful for the development of electrical and electronic industries. The workers in those industries can learn advanced processing technologies and managing approaches of recycling e-waste by reading the articles of the core journals, the entrepreneurs can formulate proper strategies and directions of their companies to comply policies or legislations by keeping familiar with the study status and trends of the core countries, institutions and experts (Davis John-Michael, Garb Yaakov 2015; Li Jinhui et al. 2015; Wang Zhe et al. 2020).

In summary, the evidences found in this study possess an overall and high completeness and applicability.

### **4.3 Potential biases in the review process**

In order to eliminate the deviation caused by the study, we have made much efforts in many ways. However, there still exists some potential biases in the review process.

The top 100 cited articles retrieved from only SCI-E database may not thoroughly cover all the most valuable studies on e-waste. The search strategies and screening criteria could miss some publications related to e-waste. In terms of citation, this study may not take some other situations into consideration.

Actually, those biases mentioned above don't affect the accuracy and reliability of the final overall results. The evidence found by this study are fundamentally of high completeness and applicability.

### **4.4 Agreements and disagreements with other researches**

Through searching in the prominent databases carefully, some studies or reviews on e-waste were found out. The comparison between this study and their results were worth taking into consideration. The representative studies would be compared and discussed as below.

The first bibliometric map analysis of e-waste research in 2012 found there were main five main cluster of interest in the field which could group in two areas: one was management assessment and policy, the other was chemical and health issues (Filippo Corsini, et al. 2012).

The latest bibliometric analysis on e-waste in 2019 found that the main hot topics were developing countries' management of e-waste, waste metal materials' recovery, and heavy metals' harm to children (Ya Gao et al. 2019).

The most cited article on e-waste in the SCI-E database concluded although limited study was accomplished on the bioleaching of metal from e-waste, biotechnology has been one of the most prospective techniques in metallurgical processing. (Cui Jirang e al. 2008).

The latest article (Li Weila et al. 2020) on e-waste in WoSCC recommended eco-friendly and efficient remediation techniques and controlled contamination sources to settle problem of e-waste in China

The most used article on e-waste in WoSCC showed that the knowledge on the ecological effects, health risks and remediation options for some e-waste contaminants is narrow, and mitigating the negative environmental effects bring special benefit to rich countries. (Robinson, Brett H 2009).

The study recommended the health risk and evidence of effects of e-waste exposure were the first choice for the international community and research agenda, especially the health of vulnerable children and the elderly (Zeng Xiang et al. 2020).

The study show that induction heating is more effective than resistance heating for e-waste processing by mathematical and experimental validation. (Hrishikesh Mishra et al. 2019).

Compared with other studies or reviews on e-waste, this study was much featured, and made a progress based on the past similar studies in the research field of e-waste.

## 4.5 Implication for practice and research

This study could provide an instructive significance for other practice and research. When people conduct practices, such as development, engineering, design etc, they had better search for the reliable evidences, which could help their activities be more scientific, operative and effective. As for research, the scholars and academics could utilize the bibliometric analysis or study better method to discover more valuable evidences.

## 5. Conclusion

To conclude, our study found the journal the *Environmental Science & Technology*, the country *China*, the institution *Chinese Academy of Sciences*, and the author *Mai Bi xian* published the maximum quantity of the 100 most-cited articles on e-waste, separately. Journal of *Hazardous Materials*, *Waste management* and *Environmental science & technology* are the core journals, and *Mai Bi xian* and *Chen She jun* can be consider to be the two most influential researchers on e-waste. The focuses of current study on e-waste are mainly the influence of e-waste on environment and health, and the management and economic of e-waste.

## Abbreviations

WoSCC Web of Science Core Collection

SCI-E Science Citation Index-Expanded

IF Impact factor

## Declarations

**Ethical approval** Not applicable

**Consent for publication** Not applicable

**Availability of data and materials** The datasets generated and/or analysed during the current study are available in the SCI-E of the WoSCC repository,  
<https://clarivate.com/webofsciencegroup/solutions/webofscience-scie/>

**Competing interests** The authors declare that they have no competing interests.

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**Authors' contributions** Xianghong Chen accomplished the comprehensive research. Jingting Wei conducted the retrieval, Liwei Chen and Bo Xie used the software tool to analyze the data. Xianghong Chen wrote the paper. Ming Liu proposed ideas and structure of the paper. All authors approved the final manuscript.

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## Figures

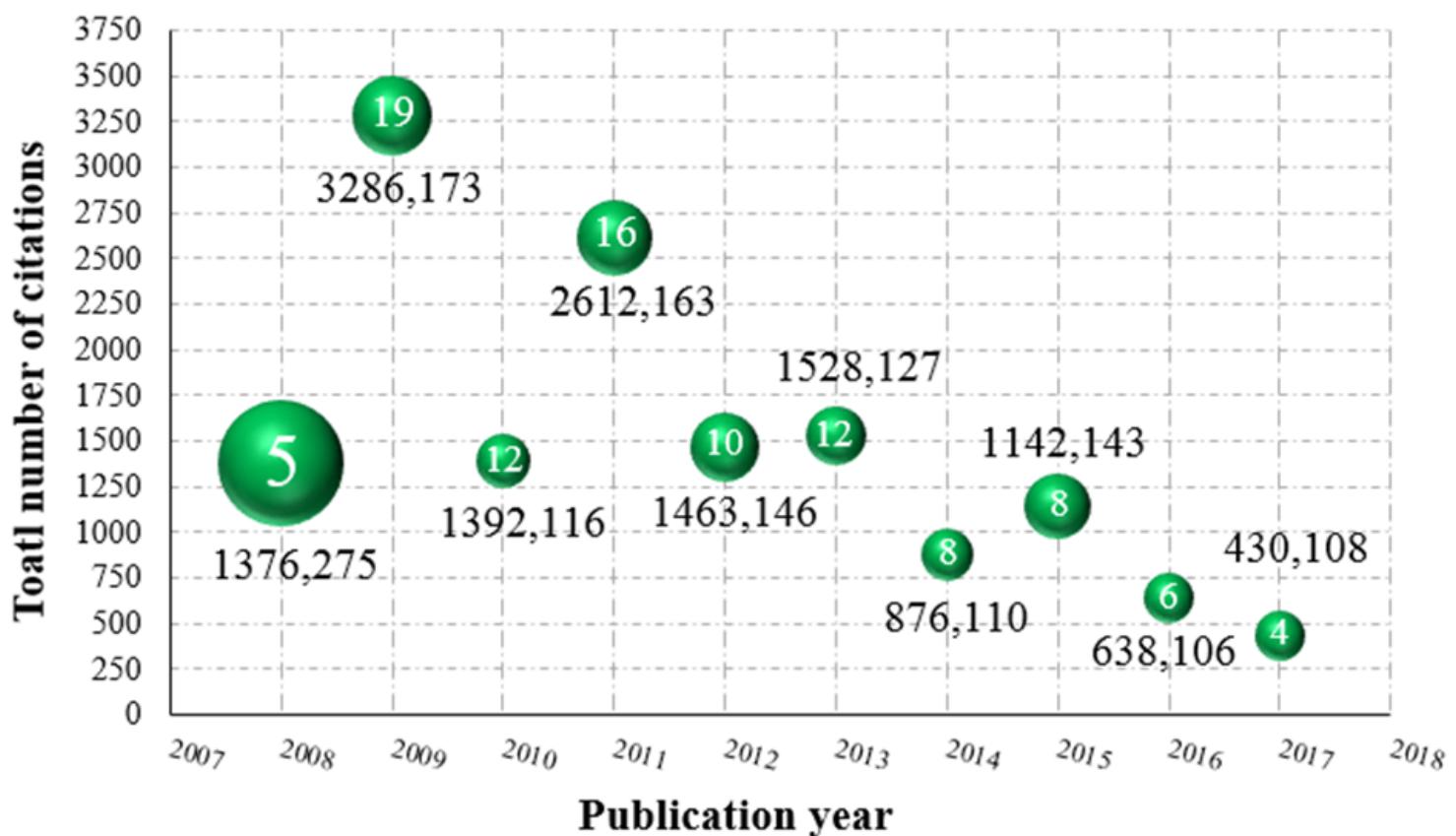
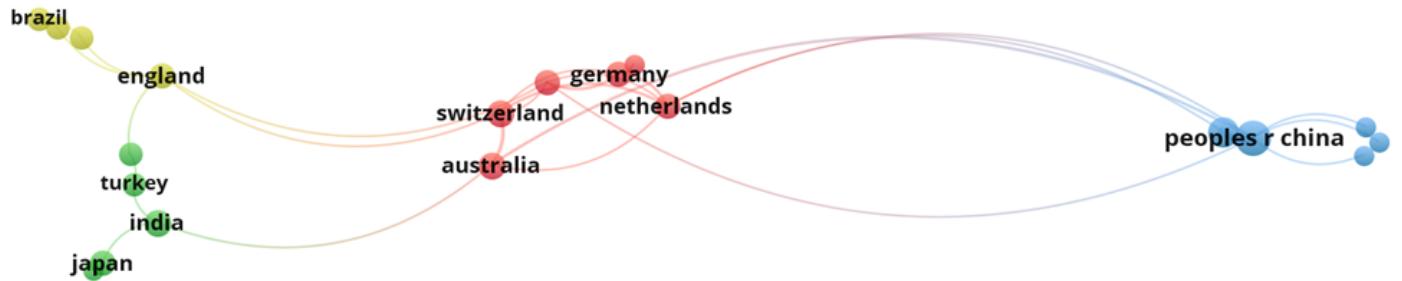


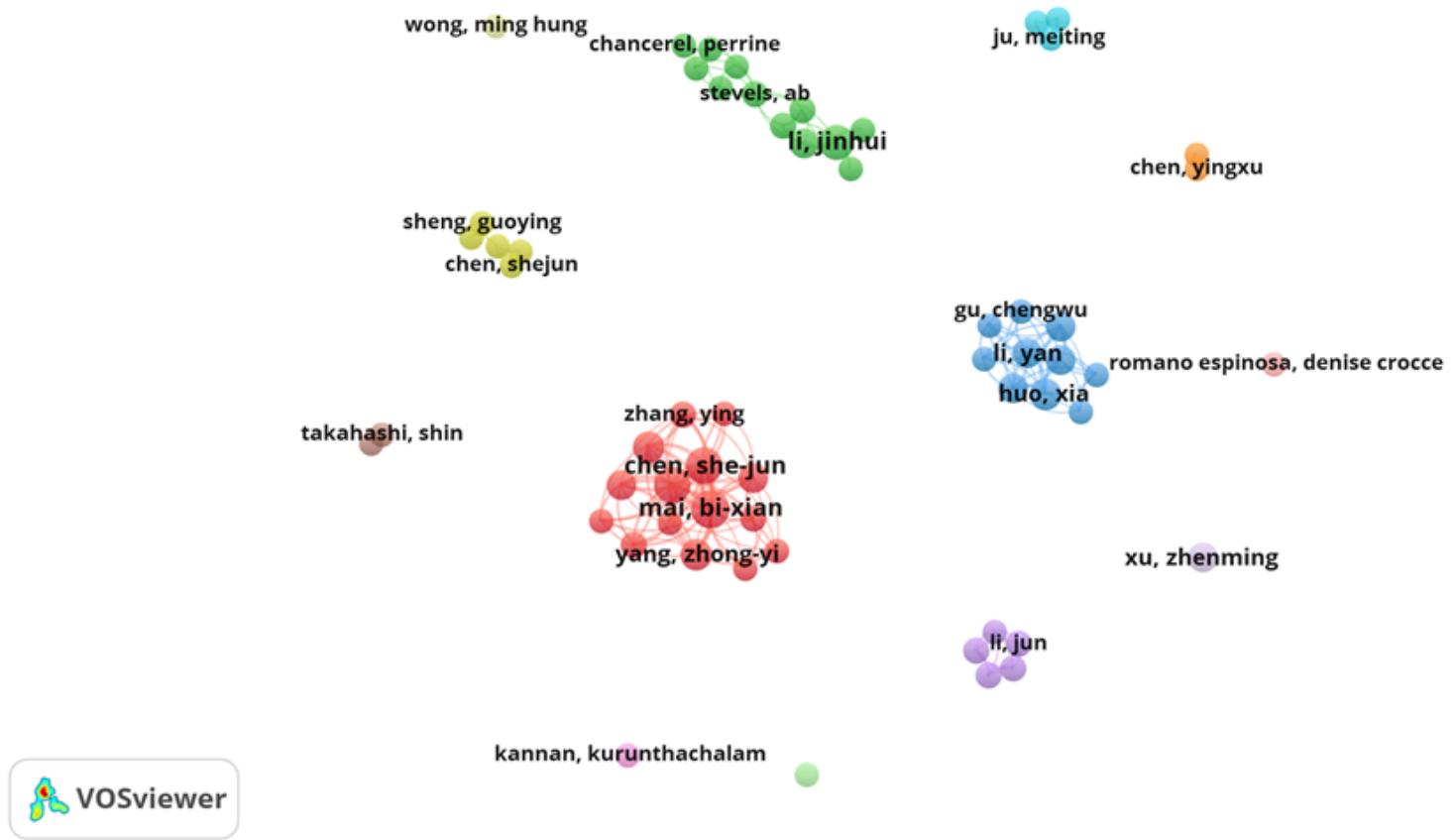
Figure 1

Bubble graph of the distribution of articles and citations by year Note: bubble size: the average quantity of citations; number on the bubble: the quantity of articles in the specific year number label: the anterior: the total number of citations; the rear: the average number of citations Y-axis: the total quantity of citations X-axis: publication year;



**Figure 2**

Cooperation among countries published the 100 articles on e-waste

**Figure 3**

Network map of author cooperation relationship who contributed two or more articles

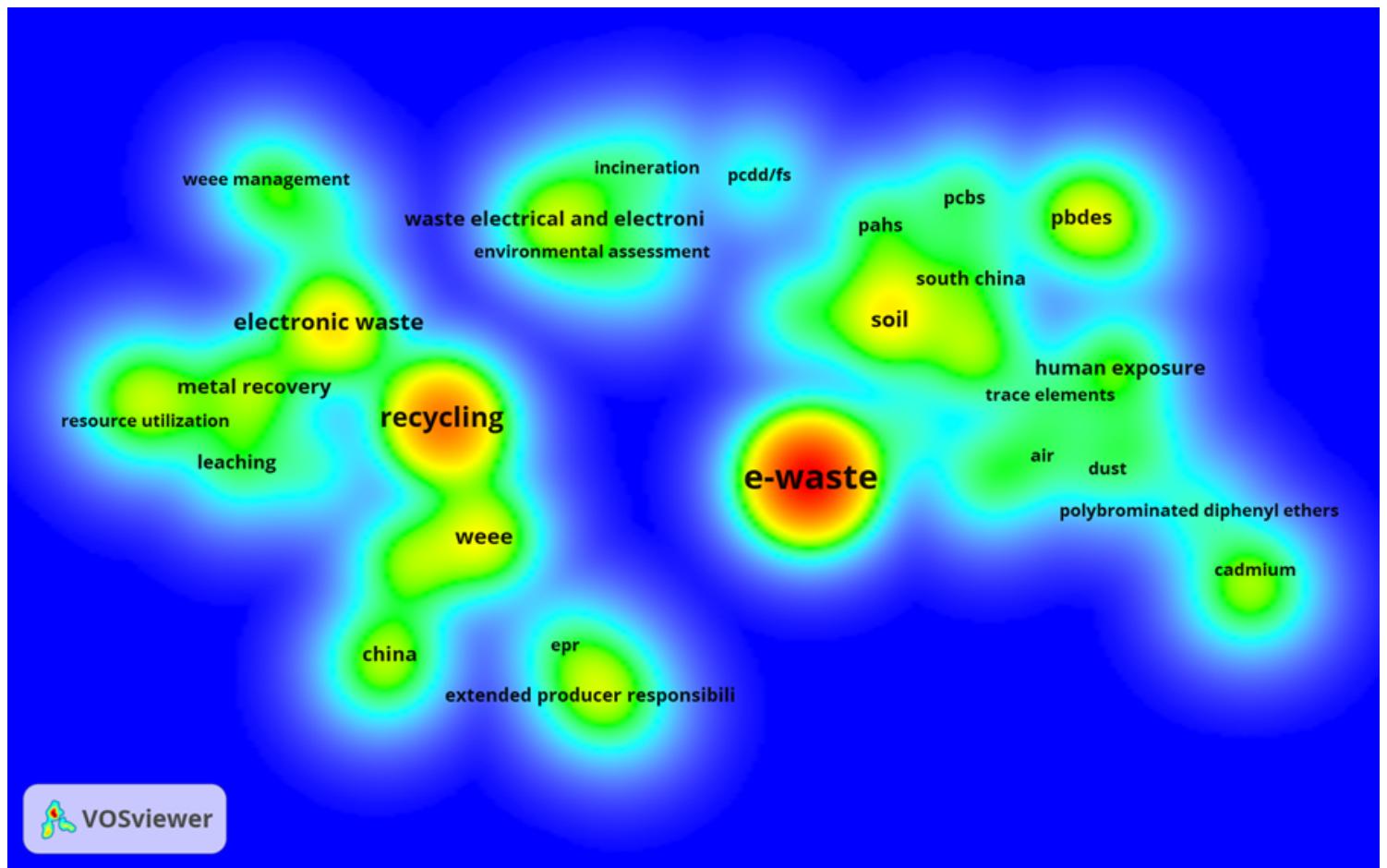
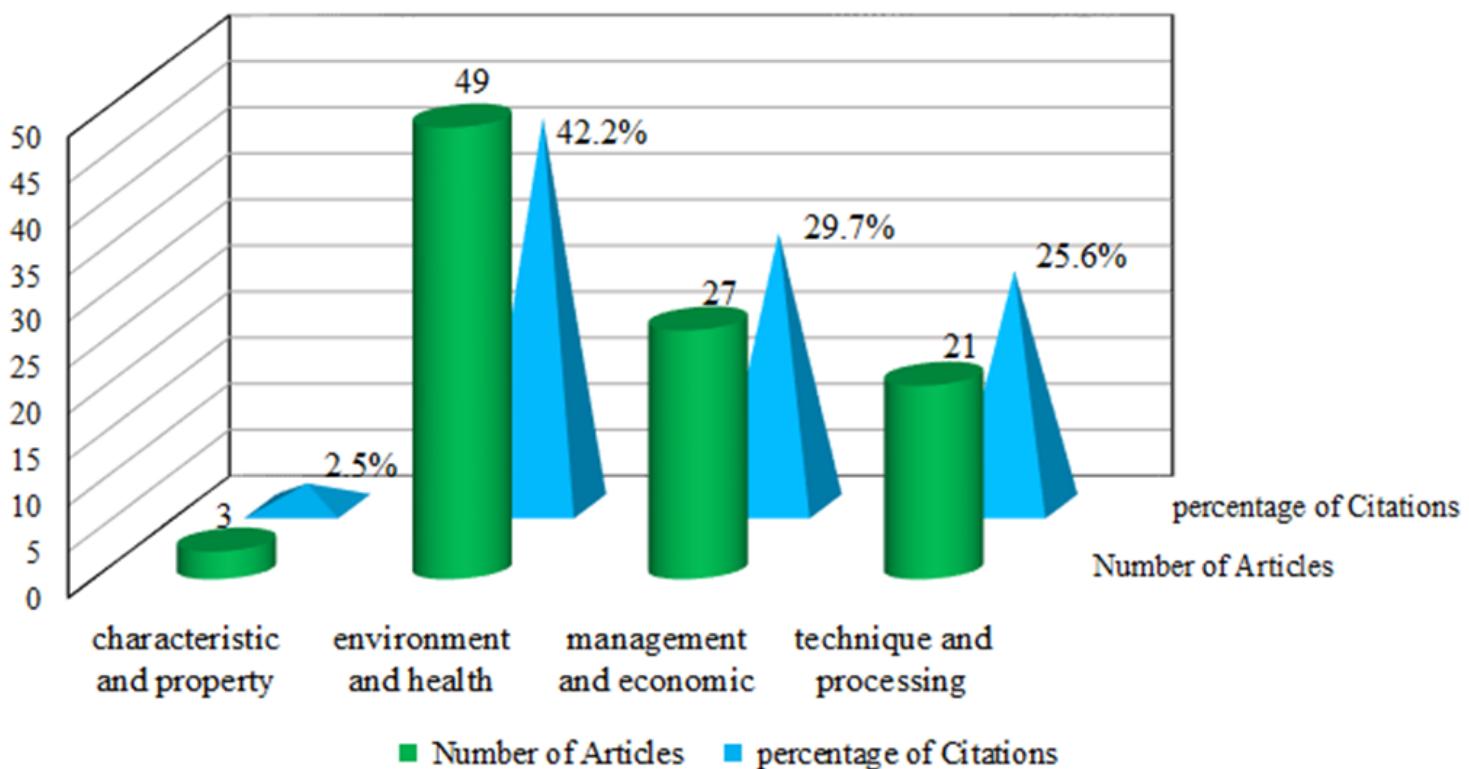


Figure 4

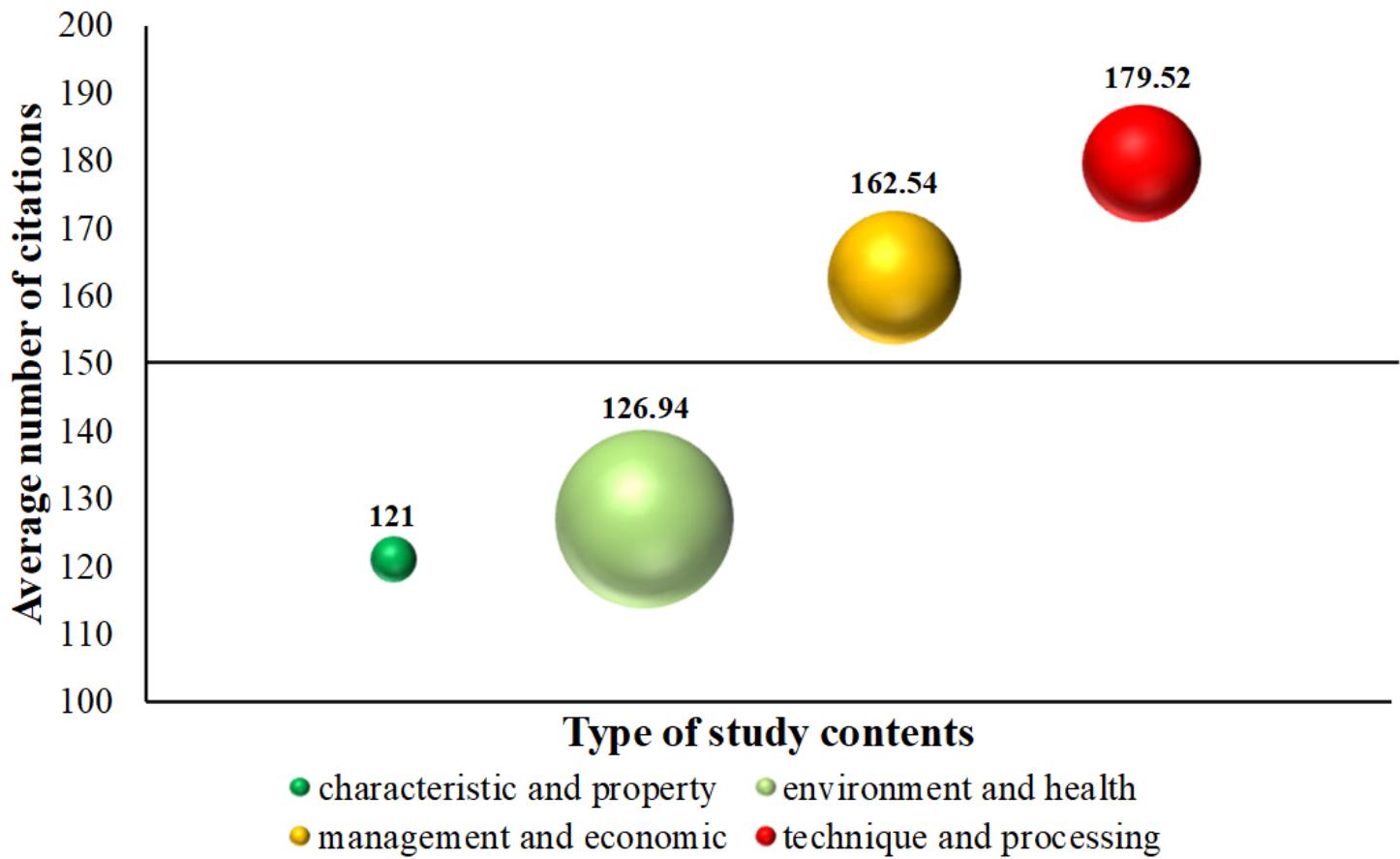
density map of keywords

## Type of study contents



**Figure 5**

the comparison for the quantity of articles and the percentage of citations of each study content type X-axis: types of study contents; the anterior Y-axis: the quantity of articles; the rear Y-axis: the percentage of citations



**Figure 6**

the average quantity of citations of each study content type bubble size: the quantity of articles of specific type Y-axis: the average quantity of citations X-axis: different types of study content

## Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- [Appendix1.doc](#)