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Global Trends of Compost Research from 1997 to 2012: A Bibliometric Analysis Based on SCI Database

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An effective bibliometric analysis was used in this study to evaluate the global scientific production of compost research during the period of 1997-2012. The data were from the database of the SCI published by the ISI Web of Science, Philadelphia, PA, USA. The articles related to compost were analyzed from the aspects including publication type and language, characteristics of articles outputs, countries, subject categories and journals and the distribution of title-words, author keywords and keyword plus used. The number of articles related to compost increased rapidly over the last 16 years with more countries participating in compost research. The developed countries attained a dominant position in the compost research while the developing countries made great progress in the share of articles in the study period. From the analysis of the title-words, author keywords and keywords plus, it can be concluded that "manure" and "sewage sludge" attracted plenty of attention in the compost research and "soil" and "heavy-metals" were the hot spots in recent years. The research focus was turning to the objects of compost application from the compost technology itself.

Keywords: Compost, Bibliometric analysis, SCI, Research trend.

INTRODUCTION

Composting is a spontaneous biological decomposition process of organic materials in a predominantly aerobic environment[1]. Composting decreases environmental problems related to the management of wastes by decreasing the volumes of waste and by killing potentially dangerous organisms[2]. There are three main methods for traditional composting *i.e.*, gathering of waste in windrows that are turned at regular intervals, static piles of waste that are aerated by deliberate passage of air within the mass and finally by gathering waste materials in a totally enclosed and controlled environment, that is, in a reactor[3]. Finished compost should be both stable and mature so that it can safely be packaged and transported and not cause adverse effects during its end use[4]. Many organic wastes, such as yard wastes[5], sewage sludge[6], municipal solid wastes[7] and agricultural wastes[8] (wood, animal dropping, *etc*.), can be good used for composting. The composts supply nutrients and organic matter, but, even more importantly, they bring beneficial microorganisms and sustain their life in the soil[9]. The addition of composts produced from organic wastes not only improves the properties of soil but also helps to solve serious environmental problems concerning disposal of large quantities of different refuses[10]. However, some municipal solid waste compost has been reported to have high salt concentrations, which can inhibit plant growth and negatively affect soil structure[11]. In addition, the presence of heavy metals in composts is also the main cause of adverse effects on animal and human health, transmitted through the food chain from soil, groundwater and plants[12]. Thus, there is still a large potential for improvement of compost products which attracted a number of researchers in the past decade.

It is noted that there is an obvious gap between the developing countries and the developed countries on the compost research. For example, as the largest developing country in the world, China has a tradition of composting and compost application. However, it is much later when China started to pay attention on composting technology and its application research compared to the developed countries[13]. However, with the rapid economic growth in recent years, many developing countries focused more and more attention on the compost research. Numerous studies have been carried out on the various aspects of the compost research.

Although more and more efforts were devoted to the compost research, most of these studies were based on hot topics or specific problems. There were few attempts to study the trends of the compost research by bibliometric method. As a method for systematic analysis, bibliometric method was used to measure scientific progress in many disciplines[14]. The derived statistics that measuring the contribution of scientific

publications within a given topic[15] could represent current research trends and be used to identify focuses of future[16].

In this study, we aim to analyze trends of global compost research during the period of 1997-2012 in order to help relevant researchers gain more information on the compost research and suggest the further research direction.

EXPERIMENTAL

This research was based on the data from the database of the SCI published by the ISI Web of Science, Philadelphia, PA, USA. "Compost*" was used as a keyword for online literature search in the SCI database from 1997 to 2012. Then the data collected were processed by Microsoft Excel. Articles originating from England, Scotland, North Ireland and Wales were regarded as from the UK. However, articles from Taiwan, Hong Kong and Macao were not grouped into the category of China. Moreover the impact factor of each journal was acquired from the 2011 Journal Citation Reports (JCR) which contains the latest information about impact factor.

In order to determine the development trend of compost study, all the articles associated with the keyword "compost*" during the past 16 years were analyzed in the aspects including the type and language of publications, characteristics of article outputs, publication distribution of countries/territories, distribution of outputs in subject categories and journals and frequency of title-words, author keywords and keywords plus.

RESULTS AND DISCUSSION

Type and language of publications: There were totally 12,828 papers related to the subject of "compost" downloaded from the database of SCI from 1997 to 2012. Articles (11,475) comprised 89.5 % in the total production which made this type absolute majority. Proceedings papers (732, 5.7 %), news items (622, 4.8 %), reviews (309, 2.4%) and meeting abstracts (216, 1.7 %) were following behind. The others were less significant including editorial materials (104), letters (61), corrections (34), book chapters (10), reprints (3) and biographical items (2). Except for articles, other types of literatures were mostly adopted for further study.

As the most popular language in the world, English was used to publish 12,251 papers which made up 95.5 % of all the publications, while other languages including Portuguese (180, 1.4 %), Spanish (100, 0.78 %), German (88, 0.69 %), Polish (54, 0.42 %), French (46, 0.36 %), Japanese (39, 0.30 %), Chinese (32, 0.25 %) were used less frequently.

Characteristics of article outputs: The articles related to compost were demonstrated in Table-1. It can be seen from the table that the annual amount of articles, cited references per paper and authors per paper increased significantly in last 16 years. The number of articles increased from 426 in 1997 to 1,079 in 2012. References cited per paper rose markedly from 19.7 to 36.2. The number of authors was only 2.7 while it increased to 4.5 in 2012. By contrast the number of articles per journal just increased slightly from 2.5 in 1997 to 2.9 in 2012. However, the article length presented a fluctuated rising trend with the average length of 8.5 pages during last 16 years.

The progression in the number of articles per year was further researched in Fig. 1. We simulated the correlation between the log-transformed number of articles and the period 1997 to 2012 by a linear equation with the coefficient of determinations ($R^2 = 0.954$). The relationship between the log-

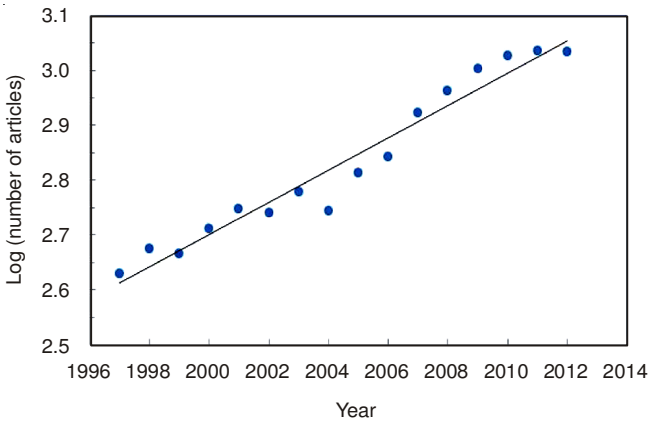

Fig. 1. Log-transformed number of articles on compost research from 1997 to 2012

TABLE-1
CHARACTERISTICS OF ARTICLE OUTPUTS FROM 1997 TO 2012

Years	A	PG	PG/A	NR	NR/A	AU	AU/A	J	A/J
1997	426	3,445	8.1	8,376	19.7	1,166	2.7	173	2.5
1998	474	3,723	7.9	9,071	19.1	1,358	2.9	183	2.6
1999	463	3,556	7.7	9,114	19.7	1,348	2.9	176	2.6
2000	514	3,917	7.6	10,662	20.7	1,564	3.0	188	2.7
2001	560	4,641	8.3	12,181	21.8	1,758	3.1	206	2.7
2002	551	4,432	8.0	12,765	23.2	1,840	3.3	205	2.7
2003	600	5,119	8.5	14,867	24.8	2,069	3.4	223	2.7
2004	554	5,017	9.1	16,187	29.2	2,053	3.7	210	2.6
2005	651	5,725	8.8	19,782	30.4	2,522	3.9	249	2.6
2006	695	6,479	9.3	22,409	32.2	2,682	3.9	257	2.7
2007	837	7,371	8.8	26,390	31.5	3,367	4.0	305	2.7
2008	917	7,864	8.6	28,834	31.4	3,660	4.0	342	2.7
2009	1,005	8,536	8.5	33,743	33.6	4,109	4.1	353	2.8
2010	1,064	9,345	8.8	37,726	35.5	4,686	4.4	381	2.8
2011	1,085	9,584	8.8	38,732	35.7	4,660	4.3	376	2.9
2012	1,079	10,014	9.3	39,018	36.2	4,878	4.5	370	2.9

A: Number of articles; PG: Page count; PG/A: Average page count per article; NR: Cited reference count; NR/A: Average cited reference count per article; AU: Number of authors; AU/A: Average authors per article; A/J: Average number of articles published per journal

transformed number of articles per year (P) and the year from 1997 to 2012 (Y) was found to be:

$$P = 0.029Y - 56.105$$

Publication distribution of countries/territories: There were 378 articles without the country or territory information in the ISI Web of Knowledge. The rest of articles were from 131 different countries/territories. Fig. 2 showed the increasing trend of the number of countries/territories which participated in the study related to compost. A steady increasing trend could be easily found from the Figure. The result made it clear that the authors from a growing number of countries/territories were becoming interested in the research of compost.

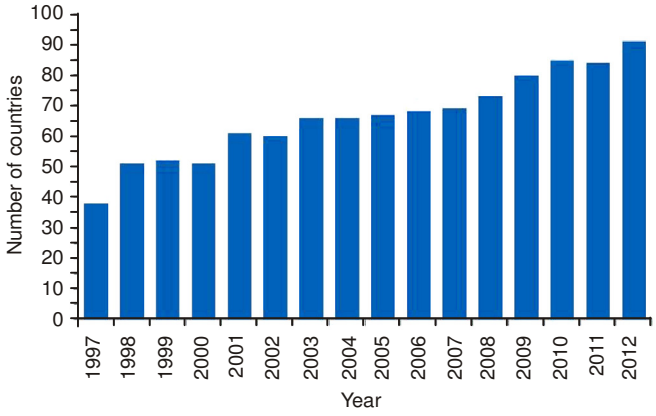

Fig. 2. Growth trends of number of countries during 1997-2012

The 20 most productive countries/territories for the articles were presented in Table-2. There were eleven European countries, 5 Asian countries/territories, 2 North American countries, 1 South American country and one Oceanian country in the list. Except for Greece and Taiwan, remained 18 countries were all from the top 25 countries in the ranking of Gross domestic product (GDP) by the World Bank. In particular, the USA, ranked first in the list, presented distinct advantage in the compost area. The number of articles from the USA was twice compared with Spain ranking second and almost triple compared with Canada ranking third in the list. Furthermore in the top 20 countries/territories, 10 countries were from the European Union (EU) and they contributed a large proportion of articles. Besides, Table-2 also presented the ranking and ratio by the number of articles changing over time. It can be seen from Table-2 that the 5 developing countries/territories in the list including China, India, Brazil, Turkey and Taiwan made great progress in correlational research. Among them, China, India and Brazil showed a notable growing trend during the last 16 years, while only Spain had a significant growth among the 15 developed countries in the list.

The developed countries and the developing countries/territories in the list were compared in Fig. 3. Though the developed countries kept a sustainable growth in the number of articles, the share of articles from the developed countries fell from 76.9 to 70 % in last 16 years. On the other hand, the number and share of articles from the developing countries/

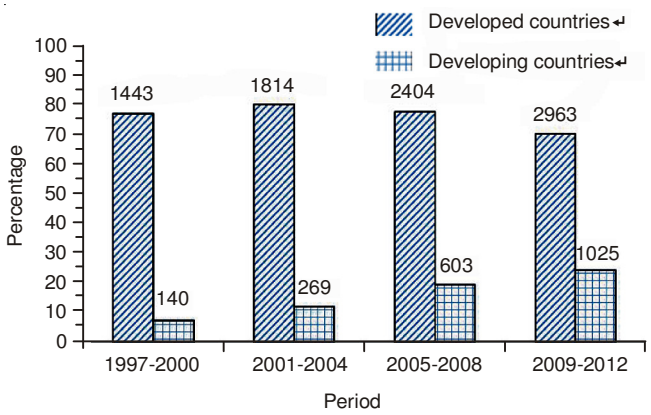

Fig. 3. Comparison between G7 and BRIC countries on the number and percentage of articles

TABLE-2
TOP 20 MOST PRODUCTIVE COUNTRIES/TERRITORIES OF ARTICLES DURING 1997–2012

Countries/territories	1997-2012 TA	1997-2012 (%)	1997-2000 R (%)	2001-2004 R (%)	2005-2008 R (%)	2009-2012 R (%)	1997-2012 change	GDP rank in 2011
USA	2290	20.0	1(36.4)	1(25.8)	1(19.9)	1(14.0)	- -	1
Spain	1078	9.4	5(5.4)	2(6.9)	2(11.7)	2(10.8)	+ +	12
Canada	714	6.2	3(7.1)	3(6.8)	3(6.8)	7(5.1)	- -	11
Japan	686	6.0	6(4.5)	4(6.7)	4(6.6)	6(5.7)	+	3
PR China	680	5.9	14(1.5)	10(3.3)	5(6.3)	3(9.0)	+ + +	2
UK	660	5.8	3(7.1)	5(6.1)	6(5.7)	8(5.0)	- -	7
India	600	5.2	8(3.4)	8(3.5)	7(5.5)	4(6.8)	+ +	10
Italy	600	5.2	7(4.2)	7(4.3)	8(5.4)	5(6.0)	+	8
Germany	530	4.6	2(8.3)	6(5.5)	10(3.9)	13(3.0)	- - -	4
France	442	3.9	11(2.0)	11(3.2)	9(4.5)	10(4.5)	+	5
Brazil	379	3.3	22(0.9)	12(2.5)	11(3.3)	9(4.8)	+ + +	6
South Korea	319	2.8	17(1.3)	9(3.4)	12(3.1)	14(2.9)	+	15
Poland	300	2.6	19(1.0)	15(1.8)	14(2.4)	11(3.9)	+	22
Australia	286	2.5	10(2.5)	15(1.8)	16(1.9)	12(3.3)		13
Turkey	202	1.8	39(0.3)	17(1.6)	13(2.4)	16(2.0)	+	18
Sweden	192	1.7	9(2.7)	19(1.5)	16(1.9)	25(1.2)	-	21
Greece	182	1.6	19(1.0)	19(1.5)	21(1.5)	17(2.0)	+	34
Belgium	181	1.6	15(1.5)	13(2.3)	20(1.4)	21(1.3)		23
Taiwan	176	1.5	17(1.3)	25(1.1)	15(1.9)	18(1.6)		-
Netherlands	164	1.4	12(1.8)	13(2.3)	27(0.9)	24(1.2)	-	17

Taiwan was not involved in the ranking of GDP by the World Bank

territories grew at a faster rate than the developed countries. Especially, the rank of China (Table-2) had climbed to the third place (2009-2012) from the fourteenth (1997-2000).

Distribution of outputs in subject categories and journals: There were more than 100 subject categories associated with the topic of compost in journal citation reports (JCR) of the ISI. The top 20 subject categories with the most articles were listed in Table-3 which contained the rank and percentage by the number of articles in four periods (every 4 years from 1997 to 2012). The 5 most popular subject categories were agriculture (5,004, 43.6 %), environmental sciences and ecology (4,371, 38.1 %), engineering (1,861, 16.2 %), biotechnology and applied microbiology (1,543, 13.4 %) and chemistry (859, 7.5 %). Among the top 20 subject categories, the fields of agriculture, environmental sciences and ecology, engineering and biotechnology and applied microbiology have kept their dominant positions in the top 4 along 16 years. The field of energy and fuels presented the most notable growth from 3.4 to 8.9 %. Besides, a significant increase could also be found in the field of engineering and biotechnology and applied microbiology. On the contrary, the article percentages of agriculture and environmental sciences and ecology had decreased sharply over the 16 years though they were still holding primacy in the research of compost. These indicated that more and more interest in compost was focused on energy development rather than agricultural application. And the direction of research was turning to deep utilization of compost products from the elimination of pollution and simple utilization of compost products in recent years.

The 11,475 articles related to compost were published in 1,338 journals. The top 20 most productive journals with their impact factors were listed in Table-4. The impact factors of these journals were determined by the data from journal citation reports in the year of 2011, which is the latest data available. There were 14 journals with more than 100 articles published in the last 16 years. Among them, Bioresource Technology, Biocycle, Compost Science and Utilization and Waste Management published the most articles from 1997 to 2012. The result indicated that biotechnology was the major technology and environmental protection was the fundamental purpose in the field of compost. It should be noticed that soil science was also a hot spot in the study period. It can also be found from Table-4 that there were half of the journals in the list with impact factors above 2 which indicated that many articles related to compost were published in the high-level journals.

TABLE-4
TOP 20 JOURNALS WITH IMPACT FACTORS DURING 1997–2012

Journals	TA	Impact factor
Bioresource Technology	659	4.98
Biocycle	569	-
Compost Science and Utilization	516	0.639
Waste Management	352	2.428
Journal of Environmental Quality	210	2.324
Chemosphere	200	3.206
Communications in Soil Science and Plant Analysis	189	0.506
Waste Management and Research	175	1.193
Soil Biology and Biochemistry	143	3.504
Journal of Hazardous Materials	133	4.173
Biology and Fertility of Soils	112	2.319
Water Science and Technology	111	1.122
Hortscience	109	0.778
Soil Science and Plant Nutrition	100	1.017
Resources Conservation and Recycling	97	1.759
Science of the Total Environment	90	3.286
Polymer Degradation and Stability	87	2.769
Environmental Pollution	84	3.746
Environmental Technology	84	1.406
Water Air and Soil Pollution	81	1.625

There was no papers published in Biocycle after 2003 which leads to a lack of its IF information in the 2011 Journal citation reports (JCR)

Analysis of title-words: The tile-words can always reflect the general information summarizing the articles, which means they can also be used in analyzing the development trends of compost. Some title-words with general meanings, such as "of", "using", "matter" and "analysis", were not included for the analysis. Besides, the title-words such as "compost" and

TABLE-3
TOP 20 SUBJECT CATEGORIES WITH THE MOST ARTICLES FOR 4-YEAR PERIODS

Subject categories	1997-2012 TA	1997-2012 (%)	1997-2000 R (%)	2001-2004 R (%)	2005-2008 R (%)	2009-2012 R (%)	1997-2012 Change
Agriculture	5004	43.6	1(52.1)	1(48.6)	1(41.4)	1(38.8)	- - -
Environmental Sciences and Ecology	4371	38.1	2(46.8)	2(41.5)	2(34.1)	2(35.4)	- -
Engineering	1861	16.2	3(13.5)	3(13.4)	3(16.9)	3(18.4)	+ +
Biotechnology and Applied Microbiology	1543	13.4	4(9.7)	4(11.8)	4(15.4)	4(14.6)	+ +
Chemistry	859	7.5	6(6.2)	5(7.1)	5(8.4)	6(7.6)	+
Energy and Fuels	806	7.0	10(3.4)	7(5.5)	6(7.8)	5(8.9)	+ + +
Plant Sciences	723	6.3	5(6.8)	6(6.1)	7(6.3)	7(6.2)	
Microbiology	539	4.7	8(4.4)	8(4.3)	8(4.8)	8(5.0)	+
Water Resources	409	3.6	9(3.6)	9(4.1)	10(3.2)	9(3.5)	
Food Science and Technology	360	3.1	11(2.0)	11(3.0)	9(3.4)	9(3.5)	+
Polymer Science	349	3.0	7(4.7)	10(3.4)	11(2.5)	11(2.6)	-
Biochemistry and Molecular Biology	210	1.8	12(1.8)	12(2.1)	12(2.1)	13(1.5)	-
Meteorology and Atmospheric Sciences	176	1.5	14(1.4)	14(1.6)	14(1.4)	12(1.6)	
Materials Science	171	1.5	13(1.5)	15(1.1)	13(1.7)	14(1.5)	
Public, Environmental and Occupational Health	165	1.4	16(1.1)	13(2.0)	15(1.3)	15(1.4)	
Toxicology	113	1.0	15(1.2)	15(1.1)	19(0.7)	18(1.0)	-
Entomology	103	0.9	22(0.6)	18(0.9)	16(1.2)	22(0.9)	+
Geology	103	0.9	23(0.5)	21(0.6)	19(0.7)	16(1.3)	+
Veterinary Sciences	103	0.9	20(0.7)	19(0.8)	17(0.9)	19(1.0)	
Marine and Freshwater Biology	94	0.8	17(1.0)	17(1.0)	23(0.6)	23(0.8)	-

"composts", "soil" and "soils" were grouped into "compost" and "soil". The rankings and percentages of the top 20 title-words were listed in Table-5. We can see from the table that "compost", "soil", "waste", "organic" and "amend" were the most 5 frequently word used in the last 16 years. The result indicated that improvement of compost technology, soil amendment and waste treatment were the hot spots in the compost research. The fast growth rate of "soil" and "plant" showed that the research focus was turning to the objects of compost application from the compost technology itself. Furthermore, it can be seen from the growth of "sludge" and "sewage" that more and more attention had been attracted to the compost technology used in the treatment of sewage sludge.

Analysis of author keywords and keywords plus: Author keyword analysis could offer the information of research trend which is concerned by researchers[17]. The statistics of author keywords revealed that 17,968 different author keywords were used altogether from 1997 to 2012. Among them, 13,321 (74.1 %) author keywords appeared only once, 2,100 (11.7 %) author keywords appeared twice and 841 (4.7 %) appeared three times. This probably indicated a lack of continuity in research and a wide disparity in research focuses[18]. The top 20 most frequently used author keywords with their rankings and percentages in each 4 year-time period were listed in Table-6. Otherwise, the author keywords such as "compost" and "composts", "heavy metal" and "heavy metals" were grouped into "compost" and "heavy metal" respectively. Except for the keyword "compost" used for searching in this study, the two most frequently used keywords were "manure" and "sewage sludge" which were highly correlated to the research topic. Composting is increasingly considered a good way for recycling the surplus of manure as a stabilised and sanitised end-product for agriculture[1]. It has been proved that composting could be used as an appropriate technique to reduce the active concentrations of antibiotics[19], which principally originate from either human pharmaceuticals entering the environment *via* wastewater treatment plants or from veterinary antibiotics entering the environment *via* application of animal manures and manure-based composts to agricultural lands[20]. Widespread concern on sludge has been raised on account of the dramatically increasing quantity of sewage sludge generated all over the world[21]. The high annual production of sewage sludge causes a series of economic, social and contamination problems[22]. Thus great efforts have been made on sludge treatment and application. Sewage sludge composting is being increasingly considered by many municipalities throughout the world because it has several advantages including providing a whole array of nutrients to the soil, decreasing soil acidification, preventing soil erosion, increasing beneficial soil organisms, reducing the need for fertilizers and pesticides, improving soil physical and biological properties and helping keep organic wastes out of landfills[23]. In addition, the author keywords "heavy metal", "soil" and "municipal solid waste" also had notable growth in last 16 years. It's worth noting that these keywords are related significantly. As mentioned above, sewage sludge composting in agriculture is now a widespread practice. However, the concentrations of heavy metals commonly found in sludges limit their application on land[24]. Heavy metals can be immobilized or aggregated by microbial hypha during composting[25,26]. Besides sewage sludge, the addition of municipal solid waste compost can also cause an increase of heavy metal concentrations in soil[27]. From another point of view, the strong metal sorption properties of compost produced from municipal solid waste or sewage sludge have important benefits for the remediation of metal contaminated industrial and urban soils[28]. On the contrary, a decline in the percentage of the keywords "biodegradation", ""biosolid", "biofilter" and "bioremediation" could be seen from the table which might imply that attention was being distracted from old biotechnology.

Keywords plus provides search terms extracted from the titles of papers cited in each new article in the database[29]. There were 9,578 papers with records that included keywords plus. 81.1 % of all 12,421 keywords plus appeared less than four

TABLE-5
TOP 20 MOST FREQUENCY OF TITLE-WORDS FOR EVERY 4-YEAR PERIOD

TI	1997-2012 TA	1997-2012 (%)	1997-2000 R (%)	2001-2004 R (%)	2005-2008 R (%)	2009-2012 R (%)	1997-2012 change
Compost	5445	25.4	1(33.8)	1(28.7)	1(23.2)	1(22.2)	- -
Soil	2775	12.9	2(10.8)	2(12.9)	2(13.3)	2(13.5)	+ +
Waste	1929	9.0	3(8.4)	3(8.1)	3(9.3)	3(9.4)	
Organic	1759	8.2	4(7.5)	4(7.2)	4(8.1)	4(9.0)	
Amend	943	4.4	5(3.7)	5(4.1)	5(4.9)	5(4.4)	+
Manure	899	4.2	7(3.6)	5(4.1)	6(4.4)	6(4.3)	
Sludge	835	3.9	8(3.4)	7(3.8)	7(4.0)	7(4.0)	+
Plant	709	3.3	13(2.4)	9(2.9)	8(3.5)	8(3.7)	+ + +
Solid	693	3.2	6(3.6)	8(3.1)	9(3.0)	9(3.3)	-
Treatment	604	2.8	9(2.9)	14(2.4)	11(2.7)	10(3.1)	
Microbial	565	2.6	15(1.9)	10(2.8)	11(2.7)	11(2.8)	+
Nitrogen	549	2.6	10(2.8)	11(2.8)	11(2.7)	17(2.3)	-
Sewage	538	2.5	16(1.8)	13(2.5)	10(2.7)	13(2.6)	+ +
Municipal	525	2.4	11(2.8)	15(2.4)	17(2.1)	12(2.6)	
Water	513	2.4	18(1.7)	12(2.6)	14(2.6)	16(2.4)	+
Chemical	483	2.3	16(1.8)	18(1.9)	15(2.4)	14(2.5)	
Management	471	2.2	14(2.0)	17(2.0)	18(2.1)	15(2.5)	+
Acid	470	2.2	12(2.5)	15(2.4)	16(2.2)	18(1.9)	-
Nutrient	387	1.8	19(1.3)	18(1.9)	19(2.0)	19(1.8)	
Contaminate	362	1.7	20(1.1)	20(1.6)	20(1.9)	20(1.7)	+

times. Table-7 showed the top 20 most active author keywords plus with their rankings and percentages in the study period. Similar with the analysis of author keywords, "soil", "manure", "sewage-sludge", "compost", "nitrogen", "organic-matter", "degradation", "heavy-metals", "municipal solid-waste", "yield", "biodegradation", "temperature" and "phosphorus" also appeared in the analysis of keywords plus. The same with Table-6, the keywords "soil", "manure", "heavy-metals" and "municipal solid-waste" also had significant growth in Table-7. Besides, "management" had a remarkable growth in the analysis of keywords plus, which means that more and more management methods were considered by the researchers.

Conclusion

For the bibliometric analysis in the subject of compost, some important points on the research trends have been obtained throughout the period of 1997-2012. In total, there were 12,828 papers downloaded from the SCI database in the study period. Among these papers, there were 11,475 articles published in 1,338 journals and English was the dominant language. The number of articles related to compost increased rapidly in the last 16 years. The 5 most popular subject categories were agriculture, environmental sciences and ecology, engineering, biotechnology and applied microbiology and chemistry. Meanwhile, the field of energy and fuels attracted more and

TABLE-6
TOP 20 MOST FREQUENCY OF AUTHOR KEYWORDS USED FOR EVERY 4-YEAR PERIOD

DE	1997-2012 TA	1997-2012 (%)	1997-2000 R (%)	2001-2004 R (%)	2005-2008 R (%)	2009-2012 R (%)	1997-2012 Change
Compost	2371	37.9	1(39.5)	1(39.1)	1(36.8)	1(37.6)	
Manure	478	7.6	3(6.1)	3(6.7)	3(7.5)	2(8.7)	+ +
Sewage sludge	463	7.4	2(8.0)	2(7.1)	2(8.0)	3(6.9)	-
Biodegradation	334	5.3	4(5.8)	4(6.0)	5(5.3)	5(4.9)	-
Heavy metal	313	5.0	5(4.0)	6(4.3)	4(5.7)	4(5.1)	+ +
Organic matter	245	3.9	7(3.2)	5(5.1)	7(3.5)	6(3.9)	+
Soil	212	3.4	8(3.0)	7(3.7)	9(3.0)	9(3.6)	+
Biofilter	205	3.3	6(3.5)	8(3.6)	6(3.7)	11(2.7)	-
Municipal solid waste	202	3.2	8(3.0)	10(2.9)	11(2.9)	8(3.7)	+
Vermicompost	192	3.1	12(2.7)	16(1.7)	8(3.2)	7(3.7)	+
Biosolid	165	2.6	8(3.0)	9(3.0)	12(2.5)	13(2.4)	-
Nitrogen	158	2.5	12(2.7)	14(2.0)	10(3.0)	14(2.4)	-
Yield	144	2.3	16(1.8)	18(1.6)	14(2.1)	10(2.9)	
Degradation	139	2.2	15(2.4)	14(2.0)	18(1.8)	12(2.6)	
Phosphorus	119	1.9	19(1.3)	12(2.2)	15(1.9)	15(1.9)	+
Ammonia	116	1.9	16(1.8)	11(2.7)	17(1.8)	17(1.5)	-
Microbial biomass	108	1.7	20(1.2)	12(2.2)	13(2.2)	18(1.3)	
Bioremediation	107	1.7	12(2.7)	16(1.7)	16(1.9)	19(1.3)	-
Temperature	98	1.6	11(2.8)	19(1.4)	18(1.8)	20(1.1)	-
Anaerobic digestion	95	1.5	18(1.5)	20(0.9)	20(1.5)	16(1.8)	

TABLE-7
TOP 20 MOST FREQUENCY OF KEYWORDS PLUS USED FOR 4-YEAR PERIODS

ID	1997-2012 TA	1997-2012 (%)	1997-2000 R (%)	2001-2004 R (%)	2005-2008 R (%)	2009-2012 R (%)	1997-2012 Change
Soil	1552	12.5	1(16.7)	1(14.9)	1(12.1)	1(11.1)	+
Manure	1133	9.1	6(6.4)	3(7.9)	3(8.4)	2(10.7)	+ +
Sewage-sludge	1092	8.8	2(9.1)	2(9.7)	2(8.6)	5(8.5)	-
Compost	1010	8.1	5(6.5)	5(6.7)	4(8.2)	3(9.0)	+
Waste	986	8.0	4(6.8)	6(6.1)	5(8.1)	4(8.8)	+
Nitrogen	747	6.0	7(5.9)	4(7.6)	7(6.5)	6(5.2)	-
Organic-matter	666	5.4	8(4.9)	8(5.4)	6(6.6)	8(4.6)	
Degradation	644	5.2	3(7.9)	7(5.9)	8(5.2)	9(4.3)	- -
Water	580	4.7	10(4.1)	9(4.5)	9(4.3)	7(5.2)	+
Carbon	513	4.1	9(4.8)	10(4.3)	10(4.1)	10(4.0)	
Heavy-metals	413	3.3	14(3.2)	12(3.0)	11(3.3)	13(3.5)	+
Municipal solid-waste	406	3.3	17(2.0)	15(2.7)	15(3.0)	10(4.0)	+ +
Management	387	3.1	20(1.4)	14(2.8)	12(3.2)	12(3.6)	+ + +
Mineralization	386	3.1	10(4.1)	11(4.2)	12(3.2)	17(2.5)	-
Maturity	355	2.9	13(3.4)	15(2.7)	18(2.4)	15(3.1)	
Yield	338	2.7	19(1.8)	20(1.6)	16(2.9)	14(3.2)	+
Biodegradation	332	2.7	12(3.7)	17(2.4)	14(3.0)	18(2.3)	-
Temperature	293	2.4	16(2.6)	18(2.3)	20(1.9)	16(2.6)	
Phosphorus	292	2.4	17(2.0)	18(2.3)	17(2.7)	19(2.2)	+
Decomposition	273	2.2	15(2.8)	12(3.0)	19(2.4)	20(1.7)	-

more attention in recent years. Bioresource Technology and Biocycle published the most articles from 1997 to 2012, which indicated that biotechnology was the major technology on the compost research.

The USA attained a dominant position in the compost research and the EU countries also contributed a large proportion of articles. Though these developed countries kept a sustainable growth in the number of articles, the share of articles from these countries fell in the last 16 years. On the contrary, the number and share of articles from the developing countries/territories, such as China, India and Brazil, grew at a faster rate than the developed countries.

According to the analysis of title-words, "compost", "soil", "waste", "organic" and "amend" were the most five frequently word used in the last 16 years. The fast growth rate of "soil" and "plant" showed that the research focus was turning to the objects of compost application from the compost technology itself. In addition, from the analysis of author keywords and keywords plus, we can conclude that "manure" and "sewage sludge" attracted plenty of attention and "soil" and "heavy-metals" were the hottest spots in the compost research. The result of this study by this new bibliometric method can help relevant researchers gain more information on the compost research and suggest the further research direction.

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