J Mater Cycles Waste Manag (2013) 15:1–8
DOI 10.1007/s10163-012-0094-5

REVIEW

A bibliometric analysis of anaerobic digestion for methane research during the period 1994–2011

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Received: 14 June 2012 / Accepted: 15 October 2012 / Published online: 9 November 2012

Abstract This study uses a bibliometric approach in identifying global research trends related to the anaerobic digestion of biomass for methane production using related literature in the Science Citation Index Expanded database, retrieved from the ISI Web of Science. The data used covers the period 1994–2011. The articles acquired from such literature were concentrated on the general analysis by scientific output, the research performances by countries, institutes, and collaborations, and the research trends by the frequency of author keywords, words in title, words in abstract, and 'KeyWords plus'. The research outputs of anaerobic digestion for methane had notably increased in the field of environmental sciences, biotechnology and applied microbiology, environmental engineering, energy and fuels, and microbiology, while increased slightly in water resources. The USA with most publications and China with the highest growth rate were compared. Finally, author keywords, words in title and 'KeyWords plus' were analyzed contrastively, with the recent hotspots provided.

Keywords Anaerobic digestion · Methane · Biogas · Research trend · Scientometrics

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Introduction

Rapid economic development in the past few years, along with the environmental crisis and the increasing price of conventional fuels, have prompted intensified research into alternative and economically attractive sources of energy [1, 2]. The amount of investments in the production of energy out of these sources has also increased [3]. Biogas research began in 1899. In 1950, an American scholar presented anaerobic digestion technology which promoted rapid development of anaerobic fermentation [4]. The benefit of methane as an energy source is that it produces few atmospheric pollutants and generates less carbon dioxide per unit energy than oil or coal [5]. The last decade was characterized by huge steps forward in terms of the development of biogas technologies and progress in the economic sustainability of both small-and large-scale biogas plants [6]. Numerous studies have been carried out on the various aspects of ADBM research, such as co-digestion [7], pretreatment [8, 9] and reactors [10]. Meanwhile, these studies were published in diverse journals of many subject categories and were written by researchers from a number of countries all over the world. However, no systematic analysis of the scientific research on ADBM research has been carried out to date.

A common research tool is based on bibliometric methods that have already been widely applied in studies on scientific production and research trends in many science and engineering disciplines [11, 12]. Furthermore, the Science Citation Index (SCI) from the Web of Science databases of the Institute for Scientific Information (ISI) is the most important and frequently used source database for broad reviews of scientific accomplishments in all fields [13, 14]. In recent years, more information, closer to the research itself, such as the distribution of different words in

the paper title [15], author keywords [16], 'Keywords Plus' [17], and words in abstracts [18] have been presented in the study of research trends.

The present study aims at synthetically using the traditional method, which includes scrutiny of the country and subject categories; the innovative method, in which author keywords, KeyWords Plus, words in title and "word cluster analysis," are considered: mapping the trends of global ADBM research from 1994 to 2011 and summarizing the predominant anaerobic digestion reactors. This approach is expected to enable researchers to realize the breadth of global ADBM research and establish its future direction.

Data sources and methods

The data on the documents used in the present study were based on the online SCI-Expanded database, retrieved from the ISI Web of Science. ''Anaero* and (biogas or methane)" were used as keywords to search titles, abstracts, and author keywords from 1994 to 2011. The data were analyzed using Microsoft Excel 2007, and the method used for data analysis was described in Mao et al. [19] literature. For the research on ADBM, author keyword and word cluster analyses were carried out using Microsoft Excel 2007.

Performance of the publication

Document type, publication output

The distribution of document types identified by the ISI was analyzed, from which nine document types were found. The article was the most frequently used document type, accounting for 77 % of total production, followed distantly by proceedings papers (17 %). Reviews (5.1 %), meeting abstracts (0.57 %), notes (0.55 %), editorial materials (0.18 %), corrections (0.11 %), letters (0.089 %), addition (0.040 %), and reprints (0.020 %) showed lower significance than did articles and proceedings papers. As the dominant type of document, 7,260 articles were then analyzed in the subsequent study.

ADBM research developed gradually before 2000 and increased rapidly in the years that followed, from 228 to 271 articles in 1994 to 2000, but from 271 articles in 2000 to 786 articles in 2011 (Fig. 1). The possible reason for the dramatic increase may be the emergence of a fossil energy crisis, the rise of energy prices, the general improvement of the energy crisis consciousness, etc. Then there was a drop of SCI-Expanded publications after the year 2009, despite the continuous increase in the year 2003–2008. The most likely reason for this drop of SCI-Expanded publications

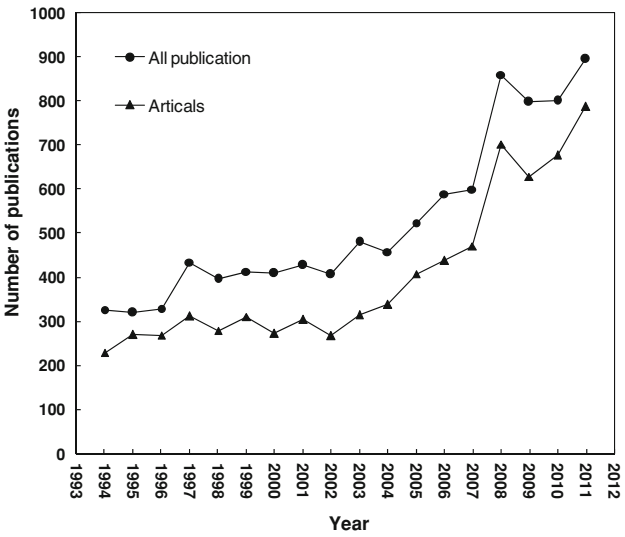

Fig. 1 Trends of SCI-Expanded publications referring to anaerobic digestion for methane production

was that the economic crisis of 2008 led to national economic difficulties. This economic crisis may have resulted in a reducton in investement in research in 2008, so that the number of SCI-Expanded publications in 2009 was affected. Overall, however, the SCI-Expanded publications were still showing a faster growth trend. Thus, the number of scientific articles on ADBM is predicted to continue growing at a high rate.

Publication patterns: subject categories and journals

Articles (7,260) were published in 777 journals in 132 subject categories in SCI. Table 1 lists the ten journals with the greatest number of published articles referring to ADBM research from 1994 to 2011. *Bioresource Technology* published the most articles, 648 (8.9 %), followed

Table 1 Top 10 most productive journals (1994–2011) with the total number of papers, *R*(%), IF

Journal	TP	*R*(%)	IF
Bioresource Technology	648	1 (8.9)	4.253
Water Research	414	2 (5.7)	4.355
Applied and Environmental Microbiology	281	3 (3.9)	3.686
Environmental Science & Technology	190	4 (2.6)	4.63
Water Science and Technology	187	5 (2.6)	1.094
Environmental Technology	153	6 (2.1)	0.762
Applied Microbiology and Biotechnology	130	7 (1.8)	2.896
Fems Microbiology Ecology	130	8 (1.8)	3.885
Process Biochemistry	123	9 (1.7)	2.444
Biotechnology and Bioengineering	121	10 (1.7)	2.398

TP total number of publications, *IF* impact factor, *R* (%) rank and percentage of total publication for a certain journal

by *Water Research* (414) and *Applied And Environmental Microbiology* (281). For comparison, the trends in the six journals with the greatest number of articles are shown in Fig. 2. The number of articles in *Bioresource Technology* and *Water Science and Technology* have increased significantly in the past two years, *Water Research* and *Environmental Science &Technology,* and *Environmental Technology* fluctuated from year to year, *Applied and Environmental Microbiology* always fluctuated and decreased in recent years. These six most productive journals consisted of 1,873 articles in total, accounting for 26 % of all methane fermentation publications.

For subject category analysis, 7,260 articles (including two articles without subject category information) were analyzed statistically. As illustrated in Fig. 3, based on the continuous increase in the number of articles per category, ADBM research has increased in the categories of biotechnology and applied microbiology, environmental sciences, environmental engineering, energy and fuels, especially microbiology, while increasing slightly in water resources. Our analysis also showed that after 2008 there was a small fall in the top six categories, except for microbiology. The possible reason for these were explained in Part 3.1. Subject categories comprising at least 1,000 articles were those that fell under the biotechnology and applied microbiology (2,208; 30 %), environmental sciences (1,959; 27 %), environmental engineering (1,208; 17 %), microbiology (1,149; 16 %), and energy and fuels (1,035; 14 %). These five most productive subject categories, all of which are branches of chemical and environmental science, consisted of 5,550 articles in total, accounting for 73 % of all methane fermentation publications.

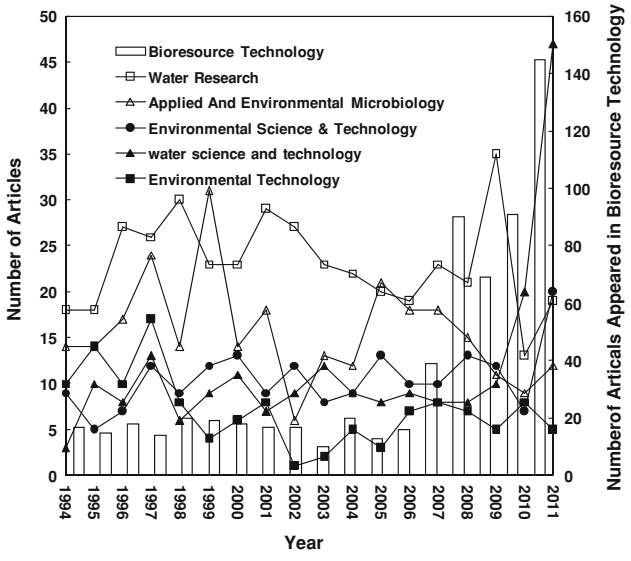

Fig. 2 The growth trends of the top 6 journals

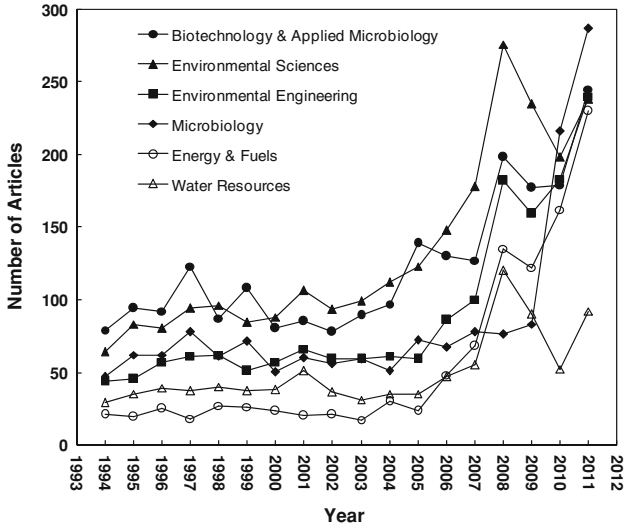

Fig. 3 The growth trends of the top six subject categories

Publication distribution of countries and institutes

The analysis of the contributions of different publications by country/territory was based on journal articles in which the address and affiliation of at least one author was provided. Articles originating from England, Scotland, Northern Ireland, and Wales were re-categorized as falling under the UK, whereas articles from Hong Kong were not included under the China category. There were 19 articles without any author address information on the ISI Web of Science, and the total number of articles for the distribution analysis of country and institute publications was 7,241.

Of 7,241 articles from 3,642 institutes in 104 countries, 5,607 (77 %) are independent articles and 1,634 (23 %) are international collaborative articles. The temporal analysis of the top six most productive countries from 1994 to 2011 is shown in Fig. 4. During the study period, the most productive country was USA, followed by German, China, and Japan. The total publications of China ranked third with 534 articles, much fewer than those of the USA (1717) and Germany (821). In the last ten years, however, the publications in China grew sharply, whereas those of other countries gradually increased. China had the highest growth rate from 5 in 1994 to 105 in 2011, followed distantly by other countries. As the country with the fastest growing economy, China paid increasing attention to environmental problems during the early years of the 21st century [20]. The number of Chinese publications on other environmental studies also began growing exponentially [21, 22].

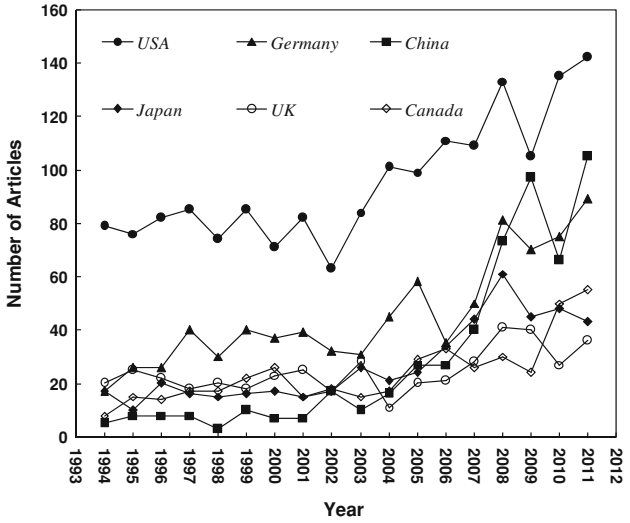

Fig. 4 Growth trends of the six most productive countries

Of 7,241 articles from 3,642 institutes in 104 countries, 3,797 (52 %) were inter-institutionally collaborative publications, and 3,444 (48 %) were independent publications. The percentage of collaboration between institutes was much higher than that between countries (29 %). The top ten most productive institutes are listed in Table 2. The Technical University of Denmark (146, 2 %), the Russian Academy Science of Russia (137, 1.9 %), and the Max Planck Institute of Marine Microbiology of Germany (110, 1.5 %) are the top three research institutes. Furthermore, in the top ten most productive institutes, there are two institutes in Germany, and one each in Denmark, Russia, Spain, the Netherlands, France, China, India, and the USA. It is worth noting that no institutes in Japan, United Kingdom or Canada can be found in the top six most productive institutes, although Japan, the United Kingdom and Canada ranked respectively 4th, 5th, and 6th in the number of articles.

Research emphasis: author keywords, words in title and 'KeyWords Plus'

The examination of author keywords in the present study reveals that 10,799 author keywords were used from 1994 to 2011; 7,933 (73 %) keywords were used only once, 1,269 (12 %) were used twice, and 507 (4.7 %) were used three times. The large number of once-only author keywords probably indicates a lack of continuity in research and a wide disparity in research aims [23]. Only 1,090 (10 %) keywords were used more than three times, indicating that mainstream research on ADBM focused on a small area. These keywords were calculated and ranked using six-year intervals to minimize year-to-year fluctuations.

Table 3 shows the 30 most frequently used author keywords along with their rankings and percentages. Through the analysis of the top 30 most frequently appearing author keywords, we could roughly draw the research trend of 1994–2011. Except for "anaerobic digestion," "biogas," "methane," "anaerobic," "anaerobic treatment," "anaerobic degradation," "methane production," (the searching words studied in the present work) "biogas production," (the searching words studied in the present work) "methanogenesis," (the meaning is the same as "methane") "biodegradation," and "fermentation," (the meaning is the same as "anaerobic digestion"), most of the top 30 author keywords were related to the following aspects: intermediate products and its impact (hydrogen, acetate, volatile fatty acids, inhibition, toxicity, sulfate reduction) (642, 12 %), reactor (UASB, UASB reactor) (253, 4.8 %), microbe (archaea methanogens) (224, 4.2 %), substrate (wastewater, wastewater treatment, sewage sludge) (221, 4.2 %), reaction condition (Thermophilic, mesophilic) (182, 3.4 %), pilot process (Hydrolysis, Denitrification) (171, 3.2 %), Kinetics (kinetics) (93,

Table 2 Top 10 most productive institutes (1994–2011)

Institution	TP	TP *R* (%)	SP *R* (%)	CP *R* (%)	FP *R* (%)	RP *R* (%)
Technical University of Denmark	146	1 (2)	1 (2.3)	7 (1.7)	1 (1.7)	1 (1.5)
Russian Academy Science	137	2 (1.9)	2 (1.8)	4 (1.9)	2 (1.4)	2 (1.4)
Max Planck Institute Marine Microbiology, Germany	110	3 (1.5)	179 (0.12)	1 (2.8)	7 (0.84)	7 (0.81)
The Spanish National Research Council	107	4 (1.5)	25 (0.58)	2 (2.3)	4 (1.1)	3 (1.3)
University Wageningen and Research Center, Netherlands	104	5 (1.4)	8 (1)	6 (1.8)	3 (1.1)	4 (0.94)
Institution national de la recherche agronomique, France	103	6 (1.4)	10 (0.93)	5 (1.9)	5 (0.9)	5 (0.9)
The University of Bremen, Germany	91	7 (1.3)	90 (0.23)	3 (2.2)	14 (0.59)	11 (0.64)
Chinese Academy of Science	86	8 (1.2)	6 (1)	9 (1.3)	8 (0.83)	6 (0.83)
Indian Institutes Technology, India	78	9 (1.1)	4 (1.4)	30 (0.79)	6 (0.86)	8 (0.8)
University of Georgia, USA	65	10 (0.9)	69 (0.29)	8 (1.4)	23 (0.51)	35 (0.36)

TP total publication, *TPR* total publication rank, *SPR* single country publication rank, *CPR* internationally collaborative publication rank, *FPR* first author publication rank, *RPR* corresponding author publication rank

Table 3 Top 30 most used author keywords, 1994–2011

Author keyword	TP	*R* (%)			
	1994–2011	1994–2011	1994–1999	2000–2005	2006–2011
Anaerobic digestion	1106	1 (21)	1 (17)	1 (16)	1 (24)
Biogas	592	2 (11)	5 (5.1)	5 (5.6)	2 (16)
Methane	493	3 (9.3)	4 (8.4)	3 (7.4)	3 (10)
Methanogenesis	333	4 (6.3)	2 (10)	2 (7.7)	4 (4.1)
Anaerobic	302	5 (5.7)	3 (10)	4 (7.2)	5 (3.4)
UASB	163	6 (3.1)	17 (2.6)	7 (3.9)	6 (2.8)
Anaerobic treatment	162	7 (3)	7 (4.4)	9 (3.5)	7 (2.3)
Biodegradation	151	8 (2.8)	11 (3.4)	6 (4.2)	10 (2)
Sulfate reduction	138	9 (2.6)	13 (3.3)	8 (3.8)	17 (1.8)
Methanogens	131	10 (2.5)	9 (3.6)	12 (2.5)	9 (2)
Inhibition	131	10 (2.5)	8 (3.8)	10 (3.1)	18 (1.7)
Hydrogen	130	12 (2.4)	11 (3.4)	11 (2.7)	10 (2)
Thermophilic	111	13 (2.1)	22 (2)	13 (2.5)	12 (1.9)
Methane production	100	14 (1.9)	19 (2.2)	28 (1.6)	13 (1.9)
Denitrification	94	15 (1.8)	14 (2.9)	16 (2.1)	38 (1.2)
Kinetics	93	16 (1.7)	15 (2.7)	14 (2.4)	41 (1.1)
Archaea	93	16 (1.7)	49 (1)	16 (2.1)	15 (1.8)
UASB reactor	90	18 (1.7)	19 (2.2)	19 (2)	31 (1.4)
Anaerobic degradation	85	19 (1.6)	15 (2.7)	15 (2.2)	48 (1)
Volatile fatty acids	83	20 (1.6)	30 (1.5)	26 (1.7)	23 (1.5)
Fermentation	82	21 (1.5)	36 (1.3)	28 (1.6)	20 (1.6)
Toxicity	81	22 (1.5)	10 (3.5)	22 (1.8)	68 (0.68)
Co-digestion	79	23 (1.5)	211 (0.3)	79 (0.65)	8 (2.3)
Acetate	79	23 (1.5)	6 (4.6)	24 (1.7)	212 (0.27)
Hydrolysis	77	25 (1.4)	77 (0.69)	26 (1.7)	20 (1.6)
Wastewater treatment	76	26 (1.4)	77 (0.69)	22 (1.8)	24 (1.5)
Wastewater	75	27 (1.4)	77 (0.69)	16 (2.1)	33 (1.3)
Biogas production	74	28 (1.4)	59 (0.89)	66 (0.72)	14 (1.9)
Mesophilic	71	29 (1.3)	77 (0.69)	28 (1.6)	29 (1.4)
Sewage sludge	70	30 (1.3)	32 (1.4)	44 (1.2)	31 (1.4)

TP number of total articles, *R* rank

1.7 %), and co-digestion (79, 1.5 %). This indicates that the research on the study of intermediate products and its impact attracted more attention to people.

During the whole study period, rankings of these author keywords shifted. The author keywords of "archaea," "hydrolysis," "wastewater treatment" "wastewater," and "co-digestion," exhibited higher growth rates than did any others, and were more frequently used in recent years—especially "co-digestion", which ranked 211st in 1994–1999, but which soared to 8th in 2006–2009. The anaerobic co-digestion of organic wastes offers the advantages of increased process stability and biogas yield, better handling of mixed waste streams, balanced nutrient supply, stable pH, optimised C/N ratio, and improved buffer capacity [24]. Co-digestion of various organic wastes for energy production has therefore attracted increasing interest recently. "Archaea," ranked 49th in 1994–1999, increased to 16th in 2000–2005, and 15th in 2006–2011. The most diverse archaea group was comprised of members of the order methanomicrobiales. Certain archaea species synthesize methane as an end product of their energy metabolism by utilizing various substrates. In order to produce more methane, in recent years the study of archaea with the help of new techniques was becoming a cause for concern [25]. The author keywords of "hydrolysis," ranked 77th between 1994 and 1999, soared to 26th in 2000–2005, and 20th in 2006–2011. Lignocellulosic waste is a large class of organic waste and a potential source of renewable energy. Therefore, the implementation of lignocellulosic waste anaerobic digestion has double significance, both in energy renewal and in environment protection. The anaerobic digestion of lignocellulosic waste to produce methane is controlled by a slow hydrolysis process [26]. Anaerobic digestion is affected by many factors, and is especially impacted by the hydrolysis process: biogas yield increases when hydrolysis increases [27].

Table 4 Top 20 most used single word in title, 1994–2011

Title	TP	*R* (%)			
	1994–2011	1994–2011	1994–1999	2000–2005	2006–2011
Anaerobic	3187	1 (44)	1 (43)	1 (45)	1 (44)
Methane	848	2 (12)	2 (10)	5 (8.8)	4 (14)
Production	822	3 (11)	7 (6.7)	9 (7.3)	2 (15)
Sludge	815	4 (11)	3 (8.6)	2 (11)	5 (13)
Digestion	809	5 (11)	8 (6.4)	4 (9)	3 (14)
Reactor	648	6 (8.9)	5 (7.6)	3 (9.9)	9 (9)
Waste	624	7 (8.6)	10 (5.5)	8 (7.6)	7 (10)
Wastewater	595	8 (8.2)	12 (4.5)	6 (8.5)	8 (9.7)
Microbial	547	9 (7.5)	9 (6.1)	6 (8.5)	10 (7.7)
Biogas	498	10 (6.9)	37 (2.5)	34 (2.8)	6 (11)
Methanogenic	476	11 (6.6)	3 (8.6)	9 (7.3)	12 (5.2)
Thermophilic	345	12 (4.8)	14 (4.1)	13 (5.3)	15 (4.8)
Degradation	334	13 (4.6)	6 (7.5)	12 (5.3)	34 (2.9)
Organic	331	14 (4.6)	20 (3.2)	19 (3.6)	11 (5.6)
Carbon	294	15 (4)	27 (2.8)	13 (5.3)	19 (4)
Solid	290	16 (4)	57 (1.9)	17 (3.7)	13 (5.1)
Process	287	17 (4)	29 (2.8)	29 (3)	14 (5)
Reactors	281	18 (3.9)	11 (4.7)	15 (4.4)	28 (3.2)
Sediments	277	19 (3.8)	19 (3.3)	18 (3.7)	18 (4.1)
Municipal	261	20 (3.6)	42 (2.3)	25 (3.2)	17 (4.4)

TP number of total articles, *R* rank

So the question of how to speed up the rate of hydrolysis was of paramount importance for scholars [26]. The author keywords "wastewater treatment" ranked 77th in 1994–1999, soared to 22nd in 2000–2005, and dropped to 24th in 2006–2011. The author keywords "wastewater," ranked 77th between 1994 and 1999, sudden increased to 16th in 2000–2005, and fell to 33rd in 2006–2011. The frequently used author keywords of "wastewater treatment," and "wastewater" in recent years pointed to the great importance that has been attached to environmental protection and energy problems. On the other hand, the author keywords "acetate" lost its research potency in the study period, since it gradually decreased in the list of frequently used author keywords. It ranked 6th in 1994–1999, fell to"24th in 2000–2005, and then descended steeply to 212th in 2006–2011.

In the title analysis, prepositions such as "of" and other meaningless words were excluded. After eliminating these words, the 20 most frequently used single substantives in the titles were analyzed, also in three six-year periods, and are shown in Table 4. On average, almost all the substantives showed a gradual increase during the investigation period, keeping in pace with the growth of the number of articles. To some extent, the results were similar to the analysis of author keywords. The distribution of the KeyWords Plus with its rank and percentage in different periods is shown in Table 5. "Reactor," "sludge," and "wastewater" were present in title, author keywords and the KeyWords Plus list, which might identify current anaerobic digestion research hotspots. Generally, the ranking of most author keywords, words in the title, and Keywords Plus fluctuated only slightly, which showed that the related research was basically steady.

Conclusions

Based on 7,260 ADBM articles dealing with SCI, this bibliometric study provided an overview of research in ADBM and identified some significant points in the research throughout the investigation period. The following conclusions were drawn from this study:

1 Anaerobic digestion for methane-related researches have significantly increased in the last 18 years, especially from 2003 to 2011.
2 There were a total of 777 journals distributed in the 132 subject categories. Anaerobic digestion for methane research had steadily increased, especially at the beginning of the 21st century in the field of biotechnology and applied microbiology, environmental sciences, environmental engineering, energy and fuels, especially microbiology, while research increased slightly in water resources.
3 The G6, with a longer tradition in research in this field, accounted for 50 % of total world production. China represented the highest growth rate. However, no

Table 5 Top 20 most used KeyWords Plus, 1994–2011

Keyword plus	TP	*R* (%)			
	1994–2011	1994–2011	1994–1999	2000–2005	2006–2011
Degradation	808	1 (12)	1 (13)	1 (15)	2 (9.7)
Digestion	607	2 (8.9)	3 (8.2)	3 (9.7)	4 (8.7)
Anaerobic-digestion	574	3 (8.8)	19 (5.1)	11 (4.9)	1 (12)
Waste-water	574	4 (8.4)	9 (6.1)	4 (9.3)	3 (8.9)
Bacteria	554	5 (8.1)	2 (9.7)	2 (11)	10 (5.8)
Sludge	495	6 (7.2)	13 (5.4)	5 (7)	5 (8.1)
Water	449	7 (6.6)	4 (7.5)	6 (7)	8 (6)
Performance	412	8 (6)	30 (3.1)	13 (4.7)	6 (7.9)
Methane	398	9 (5.8)	13 (5.4)	9 (4.9)	9 (6.4)
Biodegradation	340	10 (5)	8 (6.2)	7 (6)	21 (3.9)
Methane production	336	11 (4.9)	27 (3.4)	9 (4.9)	11 (5.6)
Reactor	313	12 (4.6)	45 (2.4)	26 (3.7)	8 (6)
Inhibition	308	13 (4.5)	10 (5.9)	20 (4.2)	20 (4)
Fermentation	303	14 (4.4)	24 (3.8)	24 (3.9)	15 (4.9)
Reduction	297	15 (4.3)	16 (5.3)	8 (5.6)	28 (3.3)
Temperature	291	16 (4.3)	29 (3.2)	22 (4)	16 (4.9)
Sediments	289	17 (4.2)	7 (6.3)	12 (4.8)	35 (3.1)
Marine-sediments	267	18 (3.9)	62 (1.6)	16 (4.3)	17 (4.7)
Acetate	261	19 (3.8)	5 (6.9)	16 (4.3)	51 (2.3)
Sulfate-reducing bacteria	249	20 (3.6)	22 (4.1)	30 (3.4)	25 (3.6)

TP number of total articles, *R* rank

institute in Japan, United Kingdom and Canada can be found in the top ten most productive institutes.

4 According to the analysis of the frequency of title-words, author keywords and 'KeyWords Plus', research on the study of intermediate products and its impact attracted more attention. In addition, the author keywords of "archaea," "hydrolysis," "wastewater," and "co-digestion" exhibited higher growth rates than did any others, and were used more frequently in recent years. This indicates that research on these aspects had drawn increasing attention of researchers, especially the research of "co-digestion".

Future perspective

The available data on ADBM indicate that we can expect development in research in this area in the near future, because of the economical and environmental advantages related to this field. In this study, "co-digestion" generates more and more concern from scholars and reveals increased progress. For further improvements in anaerobic co-digestion processes to occur, we need to expand our knowledge of the advantages of co-digestion anaerobic processes. The advantages of co-digestion have been presented in recent years, and include, for example, improved biogas yield, economic advantages derived from the sharing of equipment, easier handling of mixed wastes, and synergistic effects. However, these advantages alone are not enough and the related mechanism of co-digestion still needs further investigation. For instance, some important questions include: how does co-digestion affect the composition of VFA? What situation makes the co-digestion effect the best (alkalinity, VFA, VFA/alkalinity ratio, acetate/propionate ratio)?

Acknowledgments This study was supported by the National Natural Science Foundation (No. 51278050) and Environmental Protection Public Welfare Projects (20090006110001). The first author wishes to thank professor Yuh-shan Ho for technical support.

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