Science of the Total Environment 443 (2013) 757–765

Contents lists available at SciVerse ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Mapping of drinking water research: A bibliometric analysis of research output during 1992–2011

Hui-Zhen Fu, Ming-Huang Wang, Yuh-Shan Ho *

Department of Environmental Sciences, Peking University, Beijing 100871, People's Republic of China
Trend Research Centre, Asia University, Taichung 41354, Taiwan

HIGHLIGHTS

► Drinking water research was characterized based on SCI-Expanded during 1992–2011.
► Research emphases were obtained from title, author keywords and *KeyWords Plus*.
► Ozonation, chlorination and adsorption were common techniques and are getting popular.
► Emerging contaminants concerned arsenic, nitrate, fluoride, lead, and cadmium.

ARTICLE INFO

Article history:
Received 13 September 2012
Received in revised form 15 November 2012
Accepted 16 November 2012
Available online 8 December 2012

Keywords:
Drinking water
Keyword
Global research trend
SCI-Expanded
Scientometrics

ABSTRACT

A bibliometric analysis based on the Science Citation Index Expanded from the Web of Science was carried out to provide insights into research activities and tendencies of the global drinking water from 1992 to 2011. Study emphases included performance of publication covering annual outputs, mainstream journals, Web of Science categories, leading countries, institutions, research tendencies and hotspots. The results indicated that annual output of the related scientific articles increased steadily. *Water Research*, *Environmental Science & Technology*, and *Journal American Water Works Association* were the three most common journals in drinking water research. The USA took a leading position out of 168 countries/territories, followed by Japan and Germany. A summary of the most frequently used keywords obtained from words in paper title analysis, author keyword analysis and *KeyWords Plus* analysis provided the clues to discover the current research emphases. The mainstream research related to drinking water was water treatment methods and the related contaminants. Disinfection process and consequent disinfection by-products attracted much attention. Ozonation and chlorination in disinfection, and adsorption were common techniques and are getting popular. Commonly researched drinking water contaminants concerned arsenic, nitrate, fluoride, lead, and cadmium, and pharmaceuticals emerged as the frequently studied contaminants in recent years. Disease caused by contaminants strongly promoted the development of related research.

1. Introduction

Drinking water has long been of concern. In the beginning of the 19th century, the early research in drinking water focused on the contaminants nitrite (Spiegel, 1900), *Bacillus coli* (Savage, 1902), and toxicogenic germs (Vaughan, 1904). Purification of drinking water by ozone (Thomae, 1900), UV radiation (Sommerfeld, 1910), and chlorine (Ditthorn, 1915) for the removal of these contaminants was also reported. In the 1970s, the occurrence of organohalides in chlorinated drinking waters (Bellar et al., 1974; Rook, 1976) attracted scientists' attention. A modern parallel of attention on drinking water occurs when sufficient water is available but is so polluted or brackish that its uses are restricted (Sundstrom and Klei, 1979). Since the Industrial Revolution, consequent pollution problems have occurred and steadily increased for a long period of time. Since there has been a tremendous growth in manufacturing and the use of synthetic chemicals from World War II (Manahan, 1991), many of these chemicals, for example, insecticides and herbicides, appeared and accumulated in the environment as runoff from agricultural land. For hundreds of years, drinking water related research has become a multidisciplinary field which covers a wide spectrum including studies on environmental sciences (Kolpin et al., 2002; Wang et al., 2010), biochemistry and molecular biology (Bohl et al., 1997), and medicine research (Mackenzie et al., 1994). Today, there are also many problems in drinking water, although the control of environmental pollution has been investigated and legislated on for a long time (Bove et al., 1995; Järup, 2003). In the last decade, the removal of organic contaminants (Kolpin et al., 2002), pharmaceutical (Heberer, 2002), heavy metals (Järup, 2003), and arsenic

* Corresponding author at: Trend Research Centre, Asia University, Taichung 41354, Taiwan. Tel.: +886 4 2332 3456x1797; fax: +886 4 2330 5834.
E-mail address: ysho@asia.edu.tw (Y.-S. Ho).

0048-9697/$ – see front matter © 2012 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.scitotenv.2012.11.061

(Berg et al., 2001) from drinking water has attracted attention. It is helpful to portray the global trend of the research fields that sustain human life.

Bibliometrics is a useful tool to map the literature around a research field, which has been used in many global studies of specific fields recently (Vergidis et al., 2005; Falagas et al., 2006). It refers to the research methodology employed in library and information sciences, which utilizes quantitative analysis and statistics to describe distribution patterns of articles within a given topic, field, institution, and country. In order to analyze the global trends of research productivity in tropical medicine, the contribution of the different world regions to research and the articles published in the main journals of tropical medicine during the period of 1995–2003 were revealed (Falagas et al., 2006). Statistical methods have been employed to describe the worldwide alcohol-related research from 1992 to 2003 (Rajendram et al., 2006). An assumption is made in these studies that the number of publications of a country in a certain scientific subfield reflects its commitment to the state of science and is a reasonable indicator for the research and development efforts in that field. However, traditional bibliometric analysis in scientific research fields has many deficiencies: their original data are usually insufficient. Many studies only select several journals or categories to represent global research trends of a topic (Mela and Cimmino, 1998; Klein and Hage, 2006). *h*-index introduced in 2005 (Hirsch, 2005), now automatically provided by scientific databases, could enrich the contents of the article. The change in the citations or publication counts of countries and organizations cannot completely indicate the development trend or future orientation of the research field (Chiu and Ho, 2007). More information, closer to the research itself, including source title, author keyword, *KeyWords Plus*, and abstracts (Xie et al., 2008; Li et al., 2009a; Zhang et al., 2010) should be introduced in the study of the research trend.

Drinking water related research during the past 20 years was analyzed to provide a basis for a better understanding of the global research situation, establishing medium and long term strategies of this field. The analyzed aspects covered not only the quantitative description of publications: annual outputs, mainstream journals, Web of Science categories, and leading countries, and institutions, but also the research tendencies and hotspots obtained from the analyses of words in paper title, author keywords, and *KeyWords Plus*.

2. Methodology

The methodology used in this research was similar to other bibliometric studies (Hsieh et al., 2004; Chiu et al., 2004). Data were obtained from the online version of SCI-Expanded databases of the Web of Science from Thomson Reuters on 11 July, 2012. According to Journal Citation Reports (JCR) of 2011, it indexed 8336 journals with citation references across 176 Web of Science categories in the science edition. "Drinking water*" was searched in terms of topic within the publication year limitation from 1992 to 2011. The citations related to drinking water*, which stands for "drinking water", "drinking waters", "drinkable water", "drinkable waters", and "drinking waterborne", were downloaded. In total, 37,078 publications met the selection criteria. Journal articles were used for further analysis because they represented the majority of document types that also included whole research ideas and results (Ho et al., 2010). Altogether 30,597 original articles (88%) were used for further analysis.

Downloaded information included names of authors, contact address, title, year of publication, author keywords, *KeyWords Plus*, abstract, Web of science categories of the article, and names of journals publishing the articles. The records were downloaded into spreadsheet software, and additional coding was manually performed for the number of authors, country of origin of the collaborators, and impact factors of the publishing journals (Chuang et al., 2007). Impact factors (IF) were taken from the JCR published in 2011. *h*-Index is defined by the *h* of Np papers having at least *h* citations each and the other $(Np - h)$ papers have *h* citations each (Hirsch, 2005). Articles originating from England, Scotland, Northern Ireland, and Wales were reclassified as being from the United Kingdom (UK). Articles from Hong Kong were included under the heading of China. Contributions of different institutions and countries were estimated by the affiliation of at least one author to the publications. Collaboration type was determined by the addresses of the authors (Ho, 2007), where the term "single country article" was assigned if the researchers' addresses were from the same country. The term "internationally collaborative article" was designated to those articles that were coauthored by researchers from multiple countries. The term "single institution article" was assigned if the researchers' addresses were from the same institution. The term "inter-institutionally collaborative article" was assigned if authors were from different institutions (Malarvizhi et al., 2010).

3. Performance of publication

3.1. Publication outputs

To obtain an overview of drinking water research, the annual number of articles during 1992–2011 was displayed in Table 1. The number of drinking water publications increased from 701 in 1992 to 3129 in 2011. The most number of authors of a single article was 52, for an article published in *Neurology*, 1994, which conducted research on the health and aging-risk-factors for Alzheimer's disease in Canada (Mcdowell et al., 1994). An increasing number of journals published research papers related with drinking water. The average article lengths fluctuated slightly, with an overall average of 8.6 pages. Twenty-five references were cited per article in 1992, comparing to 39 references per article in 2011, with slight increases throughout the 20 years.

3.2. Web of Science categories and journals

The category of environmental science contributed the most with 8345 articles, followed by water resources, environmental engineering, and toxicology. Environmental sciences held primacy from 1992 to 2011. Since 2006, the number of articles in water resources and environmental engineering grew quickly and ranked 2nd and 3rd in 2011

Table 1
Characteristics by year of publication outputs from 1992 to 2011.

Year	TP	AU	AU/TP	PG	PG/TP	NR	NR/TP
1992	701	2600	3.7	5661	8.1	17,182	25
1993	724	2678	3.7	5909	8.2	18,881	26
1994	725	2878	4.0	6032	8.3	20,209	28
1995	836	3329	4.0	6969	8.3	23,720	28
1996	978	3748	3.8	8024	8.2	28,240	29
1997	973	4089	4.2	8109	8.3	27,780	29
1998	1012	4212	4.2	8166	8.1	29,173	29
1999	1130	4634	4.1	9465	8.4	33,150	29
2000	1209	5076	4.2	10,439	8.6	37,498	31
2001	1219	5127	4.2	10,501	8.6	37,467	31
2002	1382	6002	4.3	12,100	8.8	43,178	31
2003	1377	6006	4.4	12,253	8.9	44,872	33
2004	1549	6700	4.3	13,488	8.7	50,939	33
2005	1718	7787	4.5	14,906	8.7	57,682	34
2006	1896	8710	4.6	16,565	8.7	64,527	34
2007	2216	10,316	4.7	19,063	8.6	75,820	34
2008	2368	11,113	4.7	20,280	8.6	80,525	34
2009	2641	12,523	4.7	22,299	8.4	94,085	36
2010	2814	13,452	4.8	24,943	8.9	105,784	38
2011	3129	15,625	5.0	27,731	8.9	121,676	39
Average			4.5		8.6		33

TP: total articles; AU: author number; AU/TP: author number per article; PG: page count; NR: cited reference count; PG/TP: page count per article; NR/TP: cited reference count per article.

(Fig. 1). According to the category description in the Web of Science (http://admin-apps.webofknowledge.com/JCR/static_html/scope_notes/SCIENCE/2011/SCOPE_SCI.htm), environmental sciences covers resources concerning many aspects of the study of the environment, among them environmental contamination and toxicology, environmental health, environmental monitoring, environmental geology, and environmental management; environmental engineering includes resources that discuss the effects of human beings on the environment and the development of controls to minimize environmental degradation; and water resources covers resources concerning a number of water-related topics. The three most productive categories have been taking the lead, and are unlikely to be exceeded by other categories in the foreseeable future, which mainly take focus on the environmental problems of drinking water. They were also the categories with the highest growth rate and the most energy in recent years, with many kinds of treatment and protection technologies in these categories used as measures to solve problems (Mackenzie et al., 1994; Hirsch et al., 1999).

In total, 30,597 articles were published in a wide range of 3119 journals. Among these journals, 2550 (82%) journals contained less than 10 articles. Table 2 shows the top 20 productive journals, accounting for approximately 22% of the articles. *Water Research* published the most articles with 1288 articles (4.2%), while *Environmental Science & Technology* ranked second with 726 articles (2.4%). The percentage of the top productive journal was not high, which indicates the breadth of article distribution as well as the broad interest in drinking water from various research angles. This phenomenon also appears in other environment related research areas, such as *Atmospheric Environment* (8.7%) in atmospheric simulation (Li et al., 2009b) and *Journal of Geophysical Research—Atmospheres* (9.5%) in papers concerning aerosols (Xie et al., 2008). *Water Research* ranked on top in the category of water resources with an impact factor of 4.865 and an *h*-index of 64. *Water Research* was also the most productive journal in biosorption technology for water treatment (Ho, 2008). *Environmental Science & Technology* ranked third in environmental engineering with the highest impact factor of 5.228, and had the highest *h*-index of 72. The most commonly cited article was published in the 2nd position journal of *Environmental Science & Technology* with 2333 citations. It is noticeable that the 4th placer *Journal of Hazardous Materials* had a high impact factor of 4.173, but showed a relatively low *h*-index of 31 in drinking water research. The journals with the highest impact factor were *CA-A Cancer Journal for Clinicians* with one article (IF = 101.78), followed by *New England Journal of Medicine* with four articles (IF = 53.298), and *Lancet* with 14 articles (IF = 38.278).

3.3. Country/territory and institution

Domination in publication was not surprisingly from a small number of countries since this pattern has occurred in most scientific fields (Mela et al., 1999). Of 30,381 articles with author addresses, 25,000 (82%) were single country articles and 5381 (18%) were internationally collaborative articles. The geographical global distribution of drinking water research is shown in Fig. 2. There existed a great geographical diversity, covering 168 different countries or territories. According to their production, the 168 countries were divided into five parts. Particularly, 76 countries (45%) belonged to the first part with 1–10 articles; 74 countries (44%) belonged to the second part with 11–500 articles; 12 countries (7.1%) belonged to the third part with 501–1500 articles; five countries (Japan, China, Germany, Canada, and India) belonged to the fourth part with 1501–2500 articles; and only one country (the USA) which totally published 9494 articles, belonged to the fifth part with 2501–10,000 articles.

The top 20 countries, taking 86%, are listed in Table 3 with five indicators: total number of articles, single country articles, internationally collaborative articles, first author articles, and corresponding author articles (Malarvizhi et al., 2010). The percentage of internationally collaborative articles among the total articles for each country C% and *h*-index were also considered. Three American countries, ten European countries, six Asian countries, and one Oceania country, Australia, were

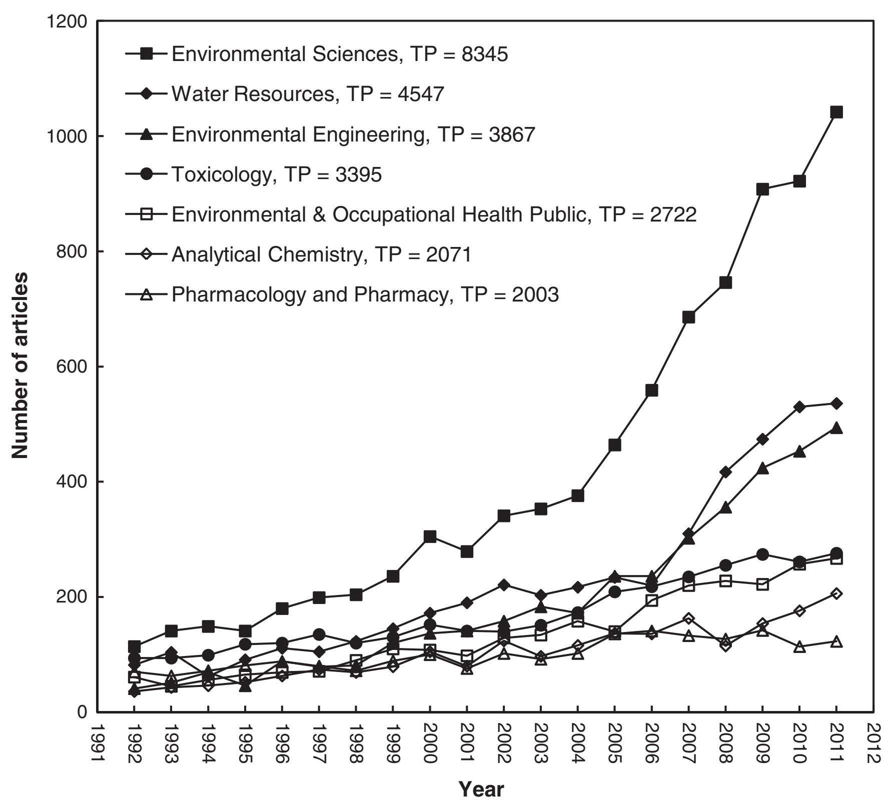

Fig. 1. Publications of the top seven productive Web of Science categories during 1992–2011.

Table 2
The 20 most productive journals with the number of articles, impact factor, *h*-index, and category of journals in its position.

Journal	TP (%)	IF	*h*-index	Web of Science category (Position)
Water Research	1288 (4.2)	4.865	64	Environmental engineering (5/45); environmental sciences (11/205); water resources (1/78)
Environmental Science & Technology	726 (2.4)	5.228	72	Environmental engineering (3/45); environmental sciences (8/205)
Journal American Water Works Association	532 (1.7)	0.633	46	Civil engineering (64/118); water resources (64/78)
Journal of Hazardous Materials	374 (1.2)	4.173	31	Environmental engineering (1/118); civil engineering (6/45); environmental sciences (17/205)
Applied and Environmental Microbiology	362 (1.2)	3.829	64	Biotechnology & applied microbiology (29/157); microbiology (28/112)
Chemosphere	330 (1.1)	3.206	39	Environmental sciences (32/205)
Science of the Total Environment	321 (1.0)	3.286	39	Environmental sciences (29/205)
Environmental Health Perspectives	304 (1.0)	7.036	53	Environmental sciences (3/205); environmental & occupational health public (2/157)
Journal of Water Supply Research and Technology—Aqua	262 (0.86)	0.935	15	Civil engineering (48/118); water resources (51/78)
Journal of Chromatography A	261 (0.85)	4.531	41	Biochemical research methods (13/72); analytical chemistry (6/73)
Environmental Monitoring and Assessment	239 (0.78)	1.4	15	Environmental sciences (118/205)
Desalination	234 (0.76)	2.59	23	Chemical engineering (23/133); water resources (5/78)
Toxicology and Applied Pharmacology	217 (0.71)	4.447	36	Pharmacology & pharmacy (32/261); toxicology (10/83)
Journal of Water and Health	206 (0.67)	1.367	12	Environmental sciences (120/205); microbiology (85/112)
Toxicology	197 (0.64)	3.681	51	Pharmacology & pharmacy (52/261); toxicology (16/83)
Water Science and Technology	194 (0.63)	1.122	9	Environmental engineering (33/45); environmental sciences (136/205); water resources (38/78)
Ozone-Science & Engineering	188 (0.61)	1.151	21	Environmental engineering (32/45); environmental sciences (134/205)
Toxicological Sciences	187 (0.61)	4.652	32	Toxicology (9/83)
Carcinogenesis	180 (0.59)	5.702	44	Oncology (23/194)
Fluoride	174 (0.57)	0.824	19	Environmental & occupational health public (127/157); toxicology (77/83)

TP: total articles; %: the percentage of articles of journals in total articles.

ranked in the top 20 of publications. There were no African countries in the top 20. The seven major industrial countries (Canada, France, Germany, Italy, Japan, the UK, and the USA) were ranked in the top 11, whose *h*-indices were all higher than 50. This comes as no coincidence, since the earliest drinking water research occurred in these industrial countries and they conducted the earliest and the most relative research performances. The USA showed the greatest counts of world publications, and also the highest *h*-index, followed distantly by other countries. It also had the most-frequent partners accounting for 43% of all the internationally collaborative articles. The publications of China and India ranked in high positions, but had relatively low *h*-indices of 53 and 48.

The top 20 institutions were ranked by the number of articles (Table 4). Among the top 20 institutions, 14 were in the USA, and one each in Brazil, Canada, China, Spain, Sweden, and Taiwan. Leading was the Environmental Protection Agency of United States (U.S. EPA) with 832 articles and the highest *h*-index, which had a large disparity with the others, and whose number of articles was more than double to that of the Chinese Academy of Sciences in China with 350 articles. The U.S. EPA also published the most independent, collaborative, first authored, and corresponding authored articles. The result of the institutions' output should be interpreted in the context of bias. The Chinese Academy of Sciences has over 100 branches in different cities. At present, the articles of the different branches are pooled under one heading, and articles divided into branches would result in different rankings (Li et al., 2009a). In addition, although the Chinese Academy of Sciences and Brazil ranked 2nd and 4th with respect to publication outputs, their *h*-indices were 27 and 23 respectively, which are even lower than that of the University of Texas which holds the 13th position with an *h*-index of 32.

4. Research tendencies and hotspots

4.1. Word analysis

The title and the author keywords, provide a reasonably detailed picture of an article's theme. The sample size of titles was the most complete, because every article certainly has its title but does not always have author keywords and *KeyWords Plus*. However, the meaning of the single words in titles sometimes does not make sense, and needs referring to the author keywords for better understanding. *KeyWords Plus* can be well understood independently, but they are generated independent of the title or author keywords, having an indirect relationship with the article's content (Garfield, 1990). The synthesized analysis of words in titles, author keywords, and *KeyWords Plus* has been developed only in recent years, and has proved to be a helpful method in revealing the research hotspots and discovering scientific research trends (Chiu and Ho, 2007; Xie et al., 2008; Li et al., 2009b). Among 30,597 articles, 22,312 articles (73%) had record information of author keywords, while 27,829 articles (91%) with *KeyWords Plus* information were analyzed. The rankings of these kinds of words according to their frequency were considered, providing important clues for the characteristics of hot issues. Then the method of word cluster was employed to identify the trends of research hot issues.

In terms of author keywords, contaminants including arsenic (1138 articles; 5.1%), fluoride (411; 1.8%), nitrate (351; 1.6%), lead (297; 1.3%), cadmium (274; 1.2%), and pharmaceuticals (143; 0.64%) attracted much attention in drinking water research. Other than the searching keyword "drinking water", the most frequently used author keyword was "arsenic", which also ranked 6th in title words. Similarly, "oxidative stress" which can be caused by chronic exposure to excessive levels of "arsenic" in drinking water (Flora, 1999) ranked 6th in the author keyword list and 13th in the *KeyWords Plus* list. Researchers paid more attention on oxidative stress that damages cellular health and is a culprit in the development of many diseases in the last 20 years. "Nitric oxide" (368; 1.6%) which is closely related to oxidative stress was also attractive, and ranked 11th in the last 20 years. Much importance on "lead" in the drinking water field is coincident with the bibliometric analysis of research on lead by Hu et al. (2010). Also, "fluoride" ranked 9th in author keywords and 23rd in words in title, as one kind of the popular contaminants causing numerous water quality problems especially in developing countries (Ayoob and Gupta, 2006; Duraiswami and Patankar, 2011). It is noticeable that no article listed pharmaceuticals as its author keyword until 1997, but "pharmaceuticals" ranked 50th in the whole study period with respect to author keywords. Pharmaceuticals was also included in the first nationwide reconnaissance of the occurrence of contaminants in the most cited article of drinking water (Kolpin et al., 2002).

Numerous water treatment methods (water treatment and drinking water treatment) (588; 2.6%) have been studied in the past years.

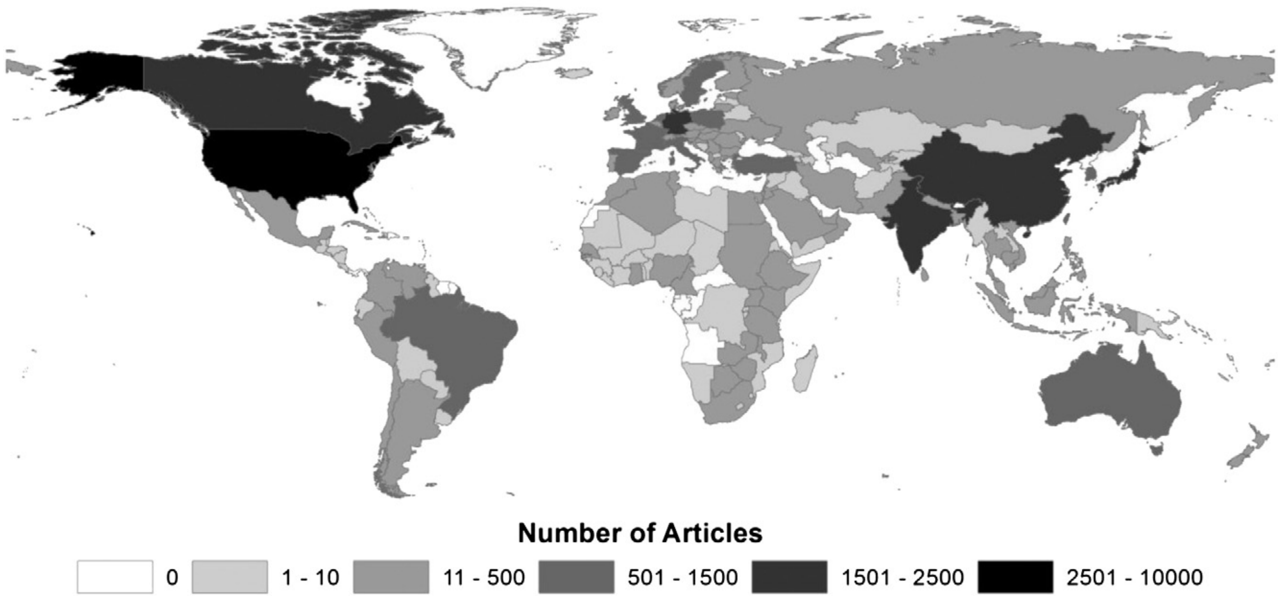

Fig. 2. Global geographical distribution of drinking water research outputs.

With respect to author keywords, "disinfection" (295; 1.3%), one typical unit during drinking water treatment processes, played an important role to protect human health (von Gunten, 2003; Duraiswami and Patankar, 2011), and therefore disinfection by-products (286; 1.3%) (Richardson, 2003) were of wide concern. "Ozone" (359; 1.6%), as an excellent disinfectant, was able to inactivate even more resistant pathogenic microorganisms (von Gunten, 2003). Because of its effectiveness in purifying and conditioning water, many municipal water companies have usually used ozonation technology to treat large quantities of water (Huber et al., 2005). Chlorination (251, 1.1%), another primary technique in traditional disinfection processes, also attracted much attention. Similarly, much concern was attracted by trihalomethanes (268; 1.2%), the toxic and cancerigenic products of chlorination in recent periods. "Adsorption" (421; 1.9%) stood in the 8th position in both author keywords and *KeyWords Plus*. Adsorption was the most popular technique and is becoming a more popular topic in drinking water research.

Moreover, the 6th "rat", 14th "rats", and 25th "mice" in author keywords, 3rd "rats", 7th "mice", and 9th "rat", in words in title, and 6th "mice", and 7th "rats" in *KeyWords Plus* indicated that rats and mice are usually used to determine the possible association between the toxic or life threatening concentration of contamination and human health (Komulainen et al., 1997; Heydarpour et al., 2008), indicating that human health was always the mainstream issue in drinking water research.

4.2. Hot issues

Word cluster analysis method which can overcome the weak points of the separated types of keyword analysis was employed to help identify the research issues (Mao et al., 2010). After the synthetic analysis of the three keywords, some valuable clues of the possible research hotspots related to treatment methods and contaminants could be obtained. Firstly, article titles, author keywords, *KeyWords Plus* and

Table 3
The top 20 most productive countries/territories.

Country	TP	*h*-index	TP R (%)	SP R (%)	CP R (%)	FP R (%)	RP R (%)	C%
USA	9494	137	1 (31)	1 (29)	1 (43)	1 (28)	1 (27)	24
Japan	2151	75	2 (7.1)	2 (6.6)	7 (9.4)	2 (6.3)	2 (6.2)	23
China	1992	53	3 (6.6)	3 (5.7)	4 (10)	3 (5.6)	3 (5.8)	28
Germany	1710	71	4 (5.6)	6 (4.2)	3 (12)	6 (4.3)	6 (4.3)	39
Canada	1668	71	5 (5.5)	5 (4.5)	5 (10)	5 (4.5)	5 (4.3)	33
India	1511	48	6 (5.0)	4 (5.0)	11 (5.0)	4 (4.5)	4 (4.5)	18
UK	1430	67	7 (4.7)	8 (3.0)	2 (13)	8 (3.5)	8 (3.4)	47
Spain	1288	56	8 (4.2)	7 (3.7)	8 (6.7)	7 (3.7)	7 (3.6)	28
France	1216	58	9 (4.0)	9 (2.8)	6 (9.4)	9 (3.0)	9 (2.9)	42
Australia	901	53	10 (3.0)	12 (2.3)	9 (5.9)	11 (2.4)	11 (2.4)	35
Italy	796	54	11 (2.6)	14 (2.1)	13 (4.9)	13 (2.2)	13 (2.2)	33
Turkey	784	30	12 (2.6)	10 (2.8)	27 (1.7)	10 (2.5)	10 (2.6)	12
Brazil	769	35	13 (2.5)	11 (2.3)	17 (3.4)	12 (2.2)	12 (2.3)	24
Taiwan	646	47	14 (2.1)	13 (2.2)	22 (2.0)	14 (1.9)	14 (2.0)	17
South Korea	617	42	15 (2.0)	16 (1.6)	16 (4.0)	15 (1.7)	15 (1.8)	35
Netherlands	571	46	16 (1.9)	17 (1.2)	12 (4.9)	17 (1.4)	17 (1.4)	46
Poland	555	29	17 (1.8)	15 (1.8)	20 (2.1)	16 (1.6)	16 (1.7)	20
Sweden	550	51	18 (1.8)	21 (1.0)	10 (5.6)	18 (1.3)	18 (1.3)	55
Switzerland	486	55	19 (1.6)	22 (0.92)	14 (4.7)	19 (1.1)	19 (1.2)	52
Finland	375	40	20 (1.2)	19 (1.1)	23 (2.0)	20 (1.0)	22 (1.0)	28

TP: total articles; TP R (%): rank and the percentage of total articles; SP R (%): rank and the percentage of independent articles; CP R (%): rank and the percentage of international collaborative articles; FP R (%): rank and the percentage of first author articles; RP P (%): rank and the percentage of the corresponding authored articles; C%: the percentage of internationally collaborative articles in the total articles of each country/territory.

Table 4
The top 20 most productive institutions.

Institutions	TP	*h*-index	TP R (%)	SP R (%)	CP R (%)	FP R (%)	RP (%)	C%
U.S. Environmental Protection Agency, USA	832	58	1 (2.7)	1 (1.9)	1 (3.5)	1 (1.8)	1 (1.9)	66
Chinese Academy of Sciences, China	350	27	2 (1.2)	2 (0.89)	3 (1.4)	2 (0.89)	2 (0.93)	62
University of North Carolina, USA	305	44	3 (1.0)	6 (0.43)	2 (1.6)	4 (0.45)	4 (0.43)	79
University of São Paulo, Brazil	215	23	4 (0.71)	3 (0.50)	7 (0.90)	3 (0.45)	3 (0.44)	65
Centers for Disease Control and Prevention, USA	196	35	5 (0.65)	86 (0.16)	4 (1.1)	12 (0.32)	9 (0.34)	88
University of Illinois, USA	187	35	6 (0.62)	5 (0.44)	9 (0.78)	5 (0.40)	5 (0.40)	65
National Taiwan University, Taiwan	185	32	7 (0.61)	18 (0.30)	7 (0.90)	6 (0.38)	7 (0.35)	76
U.S. Geological Survey, USA	176	37	8 (0.58)	4 (0.45)	12 (0.70)	7 (0.37)	6 (0.39)	62
University of California, USA	162	42	9 (0.53)	126 (0.13)	6 (0.92)	9 (0.35)	12 (0.33)	88
University of Arizona, USA	162	31	9 (0.53)	7 (0.42)	17 (0.65)	8 (0.36)	8 (0.35)	62
Harvard University, USA	159	38	11 (0.52)	203 (0.094)	5 (0.94)	32 (0.22)	28 (0.23)	91
University of Alberta, Canada	155	32	12 (0.51)	15 (0.31)	12 (0.70)	14 (0.31)	19 (0.27)	70
University of Texas, USA	150	32	13 (0.49)	9 (0.39)	20 (0.59)	10 (0.34)	10 (0.33)	61
University of California (Davis), USA	141	27	14 (0.46)	50 (0.21)	11 (0.71)	24 (0.24)	32 (0.22)	78
USDA ARS, USA	140	28	15 (0.46)	14 (0.35)	24 (0.57)	11 (0.33)	10 (0.33)	63
University of Barcelona, Spain	137	30	16 (0.45)	18 (0.30)	20 (0.59)	20 (0.27)	20 (0.26)	67
University of Washington, USA	137	33	16 (0.45)	18 (0.30)	20 (0.59)	28 (0.23)	29 (0.23)	67
Karolinska Institution, Sweden	131	33	18 (0.43)	166 (0.11)	10 (0.74)	73 (0.16)	65 (0.18)	88
University of Florida, USA	129	26	19 (0.42)	9 (0.39)	37 (0.46)	15 (0.31)	14 (0.31)	55
University of California, Los Angeles, USA	128	33	20 (0.42)	86 (0.16)	14 (0.67)	45 (0.20)	65 (0.18)	81

TP: total articles; TP R (%): rank and the percentage of total articles; SP R (%): rank and the percentage of independent articles; CP R (%): rank and the percentage of inter-institutionally collaborative articles; FP R (%): rank and the percentage of first author articles; RP P (%): rank and the percentage of the corresponding authored articles; %C: the percentage of inter-institutionally collaborative articles in the total articles of each institution.

abstracts were combined as the word base. Second, word cluster, a serious synonymic single word and congeneric phrases, were summed up by researchers using their specialized knowledge, and could represent the possible research hotspots of this field. Each word cluster was composed of several supporting words. For example, the three single words "adsorption", "sorption", and "biosorption" constitute a word cluster for a research focus of adsorption. Then the word cluster can be searched in the combined words' base to abstract the related publications. Finally, by analyzing the number of publications containing these "word clusters", the overview of the research hotspots could be revealed (Mao et al., 2010). The possible research hotspots of methods and contaminants, the two main aspects in drinking water research, were summed up.

The possible research hotspots of treatment methods of drinking water research were "adsorption", "ozonation", and "chlorination" with the most articles. "Adsorption" (adsorption, sorption, and biosorption), "ozonation" (ozonation and ozone), and "chlorination" (chlorination,

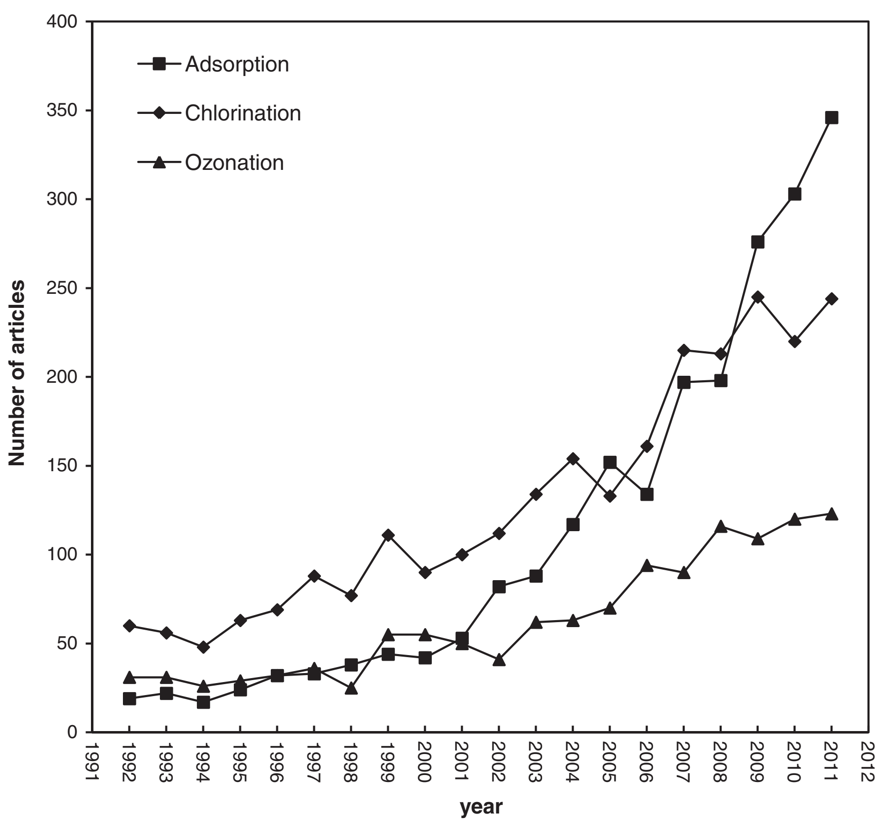

Fig. 3. Comparison of the trends of adsorption, chlorination, and ozonation in drinking water during 1992–2011.

chlorine and chlorine dioxide) were classified respectively. The article number growth trends of the three different treatment methods of drinking water are compared in Fig. 3. Studies on "adsorption" rose rapidly and have taken the lead in recent years. Analysis by *Water Research* also shows that adsorption could be the most commonly studied technique (Wang et al., 2010). This could not only be attributed to the wide application of adsorption, but could also be partly explained by the feasibility and low cost of the experiments of this technique. Adsorption method has been employed in the treatment of drinking water for more than 40 years. The early studies of adsorption in drinking water in the 1970s mainly concerned the carbon adsorption method on phenylamide pesticides (Eldib and Aly, 1977), and organics (Bottom et al., 1976). Although ozonation and chlorination had a longer history than adsorption in drinking water, adsorption has been more widely studied in the recent two decades. The articles related to chlorination surpassed ozonation since 2001 and increased quickly in the last decade.

Besides, the development of the hotspots of contaminants including arsenic (arsenic, arsenite, and arsenate), nitrate/nitrite (nitrite, denitrification, nitrate, nitric, nitrates, nitrification, and nitrites), fluoride (fluoride, defluoridation, fluoridation, fluorides, and fluorine), lead, and cadmium in drinking water was identified in Fig. 4. All research related to these contaminants rose along with the increase of the total publications. The number of articles with arsenic showed a sharp rise with the highest growth rate from 10 in 1992 to 344 in 2011, enforcing the evidence from word analysis. Arsenic was detected in drinking water in the early 1950s (Anonymous, 1950). The relation between arsenic in drinking water and the risk of skin cancer was examined in the 1980s (Astolfi et al., 1981). In the 1990s, the association between arsenic and liver, lung, bladder and kidney was also identified (Smith et al., 1992; Chen et al., 1992). It was estimated that at 50 μg/L, the lifetime risk of dying from cancer of the liver, lung, kidney, or bladder from drinking 1 L/day of water could be as high as 13 per 1000 persons (Smith et al., 1992). Since the recognition of arsenic's influence on human health in the 1980s and 1990s, various studies examined exposure to arsenic through groundwater in the USA (Taeger and Pesch, 2004), China (Chen et al., 2005; Liu et al., 2010), Taiwan (Xia and Liu, 2004), Argentina (Hopenhayn-Rich et al., 1998), India (Mazumder et al., 1998; von Ehrenstein et al., 2006), Chile (Yuan et al., 2007), and Bangladesh (Ahsan et al., 2000; Argos et al., 2010). In 2001, the U.S. Environmental Protection Agency (EPA) adopted an As standard of 10 μg/L in drinking water (U.S. EPA, 2001).

The 2nd position holder nitrate held 3219 articles during 1992–2011 and 276 articles in 2011. Cyanosis in infants caused by nitrates in well water has first been investigated in *JAMA—Journal of the American Medical Association* (Comly, 1945). Two cases of infant methemoglobinemia, also known as blue baby syndrome with blue-gray skin color, in Columbia County during June 1998 and Grant County during April 1999 were associated with water from private wells which contained nitrate-nitrogen (Knobeloch et al., 2000). The relation between nitrate in drinking water and the risk of cancer has also been discussed among scientists for more than 30 years (Jensen, 1982; Powlson et al., 2008). Since the risk of nitrate in drinking water was recognized, more than 3000 articles have been published in the last two decades, only behind the research related to arsenic. In terms of the following frequently studied contaminant, 1375 articles were published on fluoride during 1992–2011, and in 2011 there were 192 related articles. The removal of fluorine in drinking water has been studied since the 1930s (Boruff, 1934). The research related to fluorine in drinking water was mainly conducted in public environmental occupational health (Featherstone, 1999), dentistry oral surgery medicine (Magalhaes et al., 2008), and environmental sciences (Srimurali et al., 1998). Lead increased from 11 articles in 1992 to 117 in 2011, with 1003 articles in total. Lead at a low level of exposure affects the intelligence development of children (Fulton et al., 1987; Chiodo et al., 2004). The research related to lead in drinking water has become a multidisciplinary field with various studies in toxicology (Gurer et al., 1998), environmental

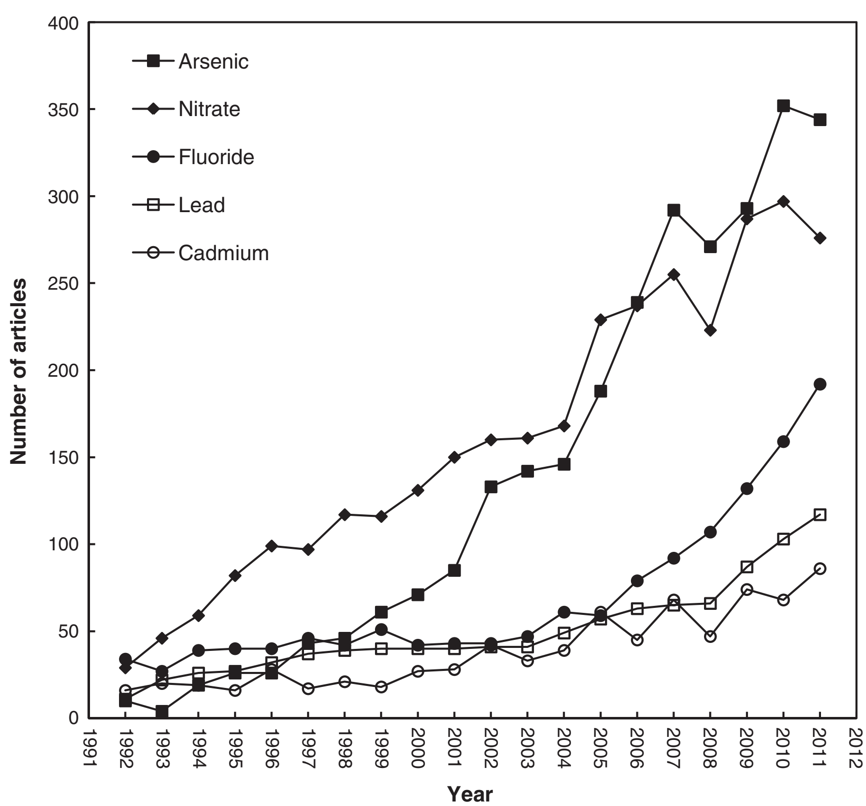

Fig. 4. Comparison of the trends of arsenic, nitrate, fluoride, lead, and cadmium in drinking water during 1992–2011.

sciences (Clement et al., 2000), pharmacology and pharmacy (Bryant, 2004), water resources (Tang et al., 2006), analytical chemistry (Grahek et al., 2006), and neurosciences (Villeda-Hernandez et al., 2001). Following lead, cadmium had 773 articles in 1992–2011, and 86 articles in 2011. In a previous study of lead in drinking water, cadmium was the most popular hotspot, together with lead (Hu et al., 2010). Cadmium exposure could induce itai-itai disease, the most serious disease first found in Japan (Tsuchiya, 1976; Satarug and Moore, 2004). Arsenic, lead, and cadmium, as the toxic environmental heavy metals, were detrimental to health and attracted much attention (Ryan et al., 2000; Järup, 2003).

5. Conclusions

An overview of the research in the drinking water field was presented with the information related to annual publications, categories, journals, institutions, countries, research emphases and tendencies. Drinking water researches increased sharply during 1992–2011. Many studies in the categories of environmental sciences, water resource, environmental engineering, and toxicology have been taken to seek for protection measures of drinking water crisis. Canada, France, Germany, Italy, Japan, the UK, and the USA had high productivity in both independent and internationally collaborative articles, especially the USA. The U.S. Environmental Protection Agency took the leading position of the institutions in total publications. The impact factor is usually used to evaluate a journal's relative importance, especially when compared to others in the same field (Benavent et al., 2004). The indicators of first author articles, corresponding author articles, and *h*-index could provide more characteristics of classical bibliometric indicators, such as those based on the number of total publications and citations. Although *h*-index played an important role in the evaluation of journals, institutions, and countries in the drinking water field, it was noticed that it may undervalue the performance of a unit with an intermediate productivity level (Costas and Bordons, 2007).

The synthesized analysis by words in title, author keywords, and *KeyWords Plus* provided the clues for hot issues. Ozonation, and chlorination with a long history were still the mainstream techniques in drinking water, while adsorption was the most commonly studied method. The contaminants including arsenic, nitrate, fluoride, lead, and cadmium are the most common research focuses and are still gaining popularity. In particular, fears about oxidative stress which can be caused by excessive levels of arsenic have arisen dramatically from 1992 to 2011. Pharmaceuticals, as the quickly increasing concern, are the emerging contaminants of drinking water. Three kinds of words, words in title, author keywords, and *KeyWords Plus*, were analyzed and are not only similar with each other in a degree to enforce the results, but also could complement one another to minimize one's shortage. This method has been proved to be an effective approach for mapping global drinking water research, and could also be adapted in other studies for the characterization of a given research field.

References

Ahsan H, Perrin M, Rahman A, Parvez F, Stute M, Zheng Y. Associations between drinking water and urinary arsenic levels and skin lesions in Bangladesh. J Occup Environ Med 2000;42:1195–201.

Anonymous. Arsenic trioxide in drinking water. JAMA 1950;142:1038.

Argos M, Kalra T, Rathouz PJ, Chen Y, Pierce B, Parvez F, et al. Arsenic exposure from drinking water and all-cause and chronic-disease mortalities in Bangladesh (HEALS): a prospective cohort study. Lancet 2010;376:252–8.

Astolfi E, Maccagno A, Fernandez JCG, Vaccaro R, Stimola R. Relation between arsenic in drinking-water and skin-cancer. Biol Trace Elem Res 1981;3:133–43.

Ayoob S, Gupta AK. Fluoride in drinking water: a review on the status and stress effects. Crit Rev Environ Sci Technol 2006;36:433–87.

Bellar TA, Lichtenberg JJ, Kroner RC. Occurrence of organohalides in chlorinated drinking waters. J Am Water Works Assoc 1974;66:703–6.

Benavent RA, Zurian JCV, Gomez MC, Melendez RS, Molina CN. Impact factor of the Spanish medical journals. Med Clin 2004;123:697–701.

Berg M, Tran HC, Nguyen TC, Pham HV, Schertenleib R, Giger W. Arsenic contamination of groundwater and drinking water in Vietnam: a human health threat. Environ Sci Technol 2001;35:2621–6.

Bohl D, Naffakh N, Heard JM. Long-term control of erythropoietin secretion by doxycycline in mice transplanted with engineered primary myoblasts. Nat Med 1997;3:299–305.

Boruff CS. Removal of fluorides from drinking waters. J Ind Eng Chem 1934;26:69–71.

Bottom CB, Magruder GC, Siehr DJ, Grigoropoulos SG, Clarke WP. Interference of elemental sulfur in determination of trace organics in drinking-water by carbon adsorption method. J Environ Sci Health A Environ Sci Eng Toxic Hazard Subst Control 1976;11:409–15.

Bove FJ, Fulcomer MC, Klotz JB, Esmart J, Dufficy EM, Savrin JE. Public drinking-water contamination and birth outcomes. Am J Epidemiol 1995;141:850–62.

Bryant SD. Lead-contaminated drinking waters in the public schools of Philadelphia. J Toxicol Clin Toxicol 2004;42:287–94.

Chen CJ, Chen CW, Wu MM, Kuo TL. Cancer potential in liver lung bladder and kidney due to ingested inorganic arsenic in drinking-water. Br J Cancer 1992;66:888–92.

Chen CJ, Hsu LI, Wang CH, Shih WL, Hsu YH, Tseng MP. Biomarkers of exposure effect and susceptibility of arsenic-induced health hazards in Taiwan. Toxicol Appl Pharmacol 2005;206:198–206.

Chiodo LM, Jacobson SW, Jacobson JL. Neurodevelopmental effects of postnatal lead exposure at very low levels. Neurotoxicol Teratol 2004;26:359–71.

Chiu WT, Ho YS. Bibliometric analysis of tsunami research. Scientometrics 2007;73:3-17.

Chiu WT, Huang JS, Ho YS. Bibliometric analysis of severe acute respiratory syndrome-related research in the beginning stage. Scientometrics 2004;61:69–77.

Chuang KY, Huang YL, Ho YS. A bibliometric and citation analysis of stroke-related research in Taiwan. Scientometrics 2007;72:201–12.

Clement M, Seux R, Rabarot S. A practical model for estimating total lead intake from drinking water. Water Res 2000;34:1533–42.

Comly HH. Cyanosis in infants caused by nitrates in well water. JAMA 1945;129:112–6.

Costas R, Bordons M. The h-index: advantages, limitations and its relation with other bibliometric indicators at the micro level. J Informetr 2007;1:193–203.

Ditthorn F. Article for the sterilisation of drinking water with chlorine. Deut Med Wochenschr 1915;41:1127.

Duraiswami RA, Patankar U. Occurrence of fluoride in the drinking water sources from Gad River Basin Maharashtra. J Geol Soc India 2011;77:167–74.

Eldib MA, Aly OA. Removal of phenylamide pesticides from drinking waters. 2. Adsorption on powdered carbon. Water Res 1977;11:617–62.

Falagas ME, Karavasiou AI, Bliziotis IA. A bibliometric analysis of global trends of research productivity in tropical medicine. Acta Trop 2006;99:155–9.

Featherstone JDB. Prevention and reversal of dental caries: role of low level fluoride. Community Dent Oral Epidemiol 1999;27:31–40.

Flora SJS. Arsenic-induced oxidative stress and its reversibility following combined administration of N-acetylcysteine and meso 23-dimercaptosuccinic acid in rats. Clin Exp Pharmacol Physiol 1999;26:865–9.

Fulton M, Thomson G, Hunter R, Raab G, Laxen D, Hepburn W. Influence of blood lead on the ability and attainment of children in Edinburgh. Lancet 1987;329:1221–6.

Garfield E. *KeyWords Plus*™ — ISIS breakthrough retrieval method. 1. Expanding your searching power on current-contents on diskette. Curr Contents 1990;32:5–9.

Grahek Z, Macefat MR, Lulic S. Isolation of lead from water samples and determination of Pb-210. Anal Chim Acta 2006;560:84–93.

Gurer H, Ozgunes H, Neal R, Spitz DR, Ercal N. Antioxidant effects of n-acetylcysteine and succimer in red blood cells from lead-exposed rats. Toxicology 1998;128:181–9.

Heberer T. Occurrence fate and removal of pharmaceutical residues in the aquatic environment: a review of recent research data. Toxicol Lett 2002;131:5-17.

Heydarpour F, Amini B, Kalantari S, Rostami A, Heydarpour P. Determination of tolerable and toxic salt concentrations in drinking water in rat pig and rabbit. Toxicol Environ Chem 2008;90:1115–23.

Hirsch JE. An index to quantify an individual's scientific research output. Proc Natl Acad Sci U S A 2005;102:16569–72.

Hirsch R, Ternes T, Haberer K, Kratz KL. Occurrence of antibiotics in the aquatic environment. Sci Total Environ 1999;225:109–18.

Ho YS. Bibliometric analysis of adsorption technology in environmental science. J Environ Prot Sci 2007;1:1-11.

Ho YS. Bibliometric analysis of biosorption technology in water treatment research from 1991 to 2004. Int J Environ Pollut 2008;34:1-13.

Ho YS, Satoh H, Lin SY. Japanese lung cancer research trends and performance in Science Citation Index. Intern Med 2010;49:2219–28.

Hopenhayn-Rich C, Biggs ML, Smith AH. Lung and kidney cancer mortality associated with arsenic in drinking water in Cordoba, Argentina. Int J Epidemiol 1998;27:561–9.

Hsieh WH, Chiu WT, Lee YS, Ho YS. Bibliometric analysis of patent ductus arteriosus treatments. Scientometrics 2004;60:205–15.

Hu J, Ma YW, Zhang L, Gan F, Ho YS. A historical review and bibliometric analysis of research on lead in drinking water field from 1991 to 2007. Sci Total Environ 2010;408:1738–44.

Huber MM, Gobel A, Joss A, Hermann N, Loffler D, McArdell CS, et al. Oxidation of pharmaceuticals during ozonation of municipal wastewater effluents: a pilot study. Environ Sci Technol 2005;39:4290–9.

Järup L. Hazards of heavy metal contamination. Br Med Bull 2003;68:167–82.

Jensen OM. Nitrate in drinking-water and cancer in Northern Jutland Denmark with special reference to stomach-cancer. Ecotoxicol Environ Saf 1982;6:258–67.

Klein S, Hage JJ. Measurement calculation and normal range of the ankle-arm index: a bibliometric analysis and recommendation for standardization. Ann Vasc Surg 2006;20:282–92.

Knobeloch L, Salna B, Hogan A, Postle J, Anderson H. Blue babies and nitrate-contaminated well water. Environ Health Perspect 2000;108:675–8.

Kolpin DW, Furlong ET, Meyer MT, Thurman EM, Zaugg SD, Barber LB, et al. Pharmaceuticals, hormones and other organic wastewater contaminants in U.S. streams 1999–2000: a national reconnaissance. Environ Sci Technol 2002;36:1202–11.

Komulainen H, Kosma VM, Vaittinen SL, Vartiainen T, KalisteKorhonen E, Lotjonen S, et al. Carcinogenicity of the drinking water mutagen 3-chloro-4-(dichloromethyl)-5-hydroxy-2(*5H*)-furanone in the rat. J Natl Cancer Inst 1997;89:848–56.

Li JF, Zhang YH, Wang XS, Ho YS. Bibliometric analysis of atmospheric simulation trends in meteorology and atmospheric science journals. Croat Chem Acta 2009a;82:695–705.

Li LL, Ding GH, Feng N, Wang MH, Ho YS. Global stem cell research trend: bibliometric analysis as a tool for mapping of trends from 1991 to 2006. Scientometrics 2009b;80:39–58.

Liu CP, Luo CL, Gao Y, Li FB, Lin LW, Wu CA, et al. Arsenic contamination and potential health risk implications at an abandoned tungsten mine southern China. Environ Pollut 2010;158:820–6.

Mackenzie WR, Hoxie NJ, Proctor ME, Gradus MS, Blair KA, Peterson DE, et al. A massive outbreak in Milwaukee of cryptosporidium infection transmitted through the public water-supply. N Engl J Med 1994;331:161–7.

Magalhaes AC, Rios D, Moino AL, Wiegand A, Attin T, Buzalaf MAR. Effect of different concentrations of fluoride in dentifrices on dentin erosion subjected or not to abrasion in situ/ex vivo. Caries Res 2008;42:112–6.

Malarvizhi R, Wang MH, Ho YS. Research trends in adsorption technologies for dye containing wastewaters. World Appl Sci J 2010;8:930–42.

Manahan SE. Environmental chemistry. Mich: Chelsea, Lewis Publishers; 1991.

Mao N, Wang MH, Ho YS. A bibliometric study of the trend in articles related to risk assessment published in Science Citation Index. Hum Ecol Risk Assess 2010;16:801–24.

Mazumder DN, Das Gupta J, Santra A, Pal A, Ghose A, Sarkar S. Chronic arsenic toxicity in west Bengal—the worst calamity in the world. J Indian Med Assoc 1998;96:4–7.

Mcdowell I, Hill G, Lindsay J, Helliwell B, Costa L, Beattie L, et al. The Canadian study of health and aging — risk-factors for Alzheimer's disease in Canada. Neurology 1994;44:2073–80.

Mela GS, Cimmino MA. An overview of rheumatological research in the European Union. Ann Rheum Dis 1998;57:643–7.

Mela GS, Cimmino MA, Ugolini D. Impact assessment of oncology research in the European Union. Eur J Cancer 1999;35:1182–6.

Powlson DS, Addisott TM, Benjamin N, Cassman KG, de Kok TM, van Grinsven H, et al. When does nitrate become a risk for humans? J Environ Qual 2008;37:291–5.

Rajendram R, Lewison G, Preedy V. Worldwide alcohol-related research and the disease burden. Alcohol Alcohol 2006;41:99-106.

Richardson SD. Disinfection by-products and other emerging contaminants in drinking water. TRAC Trends Anal Chem 2003;22:666–84.

Rook JJ. Haloforms in drinking water. J Am Water Works Assoc 1976;68:168–72.

Ryan PB, Huet N, MacIntosh DL. Longitudinal investigation of exposure to arsenic cadmium and lead in drinking water. Environ Health Perspect 2000;108:731–5.

Satarug S, Moore MR. Adverse health effects of chronic exposure to low-level cadmium in foodstuffs and cigarette smoke. Environ Health Perspect 2004;112:1099–103.

Savage WG. The significance of *Bacillus coli* in drinking water. J Hyg 1902;2:320–57.

Smith AH, Hopenhaynrich C, Bates MN, Goeden HM, Hertzpicciotto I, Duggan HM, et al. Cancer risks from arsenic in drinking-water. Environ Health Perspect 1992;97:259–67.

Sommerfeld A. The distribution of intensity in the emission of UV-rays. Z Phys 1910;11:99-101.

Spiegel L. The significance of the nitrite-evidence in drinking water. Ber Dtsch Chem Ges 1900;33:639–44.

Srimurali M, Pragathi A, Karthikeyan J. A study on removal of fluorides from drinking water by adsorption onto low-cost materials. Environ Pollut 1998;99:285–9.

Sundstrom DW, Klei HEC. Wastewater treatment. Englewood Cliffs, London: Prentice-Hall; 1979.

Taeger D, Pesch B. Arsenic in drinking water and bladder cancer mortality in the United States: an analysis based on 133 U.S. counties and 30 years of observation. J Occup Environ Med 2004;46:1007–8.

Tang ZJ, Hong S, Xiao WZ, Taylor J. Impacts of blending ground surface and saline waters on lead release in drinking water distribution systems. Water Res 2006;40:943–50.

Thomae C. The World's Fair in Paris 1900. Purification of drinking water by ozone. Z Ver Dtsch Ing 1900;44:1685–8.

Tsuchiya K. Epidemiological studies on cadmium in environment in Japan: etiology of itai-itai disease. Fed Proc 1976;35:2412–8.

U.S. EPA. National primary drinking water regulations; arsenic and clarifications to compliance and new source contaminants monitoring. Fed Regist 2001;66:50961–3.

Vaughan VC. Some toxicogenic germs found in drinking water. JAMA 1904;42:935–41.

Vergidis PI, Karavasiou AI, Paraschakis K, Bliziotis IA, Falagas ME. Bibliometric analysis of global trends for research productivity in microbiology. Eur J Clin Microbiol Infect Dis 2005;24:342–5.

Villeda-Hernandez J, Barroso-Moguel R, Mendez-Armenta M, Nava-Ruiz C, Huerta-Romero R, Rios C. Enhanced brain regional lipid peroxidation in developing rats exposed to low level lead acetate. Brain Res Bull 2001;55:247–51.

von Ehrenstein OS, Guha Mazumder DN, Hira-Smith M, Ghosh N, Yuan Y, Windham G, et al. Pregnancy outcomes infant mortality and arsenic in drinking water in West Bengal India. Am J Epidemiol 2006;163:662–9.

von Gunten U. Ozonation of drinking water: part II. Disinfection and by-product formation in presence of bromide iodide or chlorine. Water Res 2003;37:1469–87.

Wang MH, Yu TC, Ho YS. A bibliometric analysis of the performance of water research. Scientometrics 2010;84:813–20.

Xia Y, Liu J. An overview on chronic arsenism via drinking water in PR China. Toxicology 2004;198:25–9.

Xie SD, Zhang J, Ho YS. Assessment of world aerosol research trends by bibliometric analysis. Scientometrics 2008;77:113–30.

Yuan Y, Marshall G, Ferreccio C, Steinmaus C, Selvin S, Liaw J, et al. Acute myocardial infarction mortality in comparison with lung and bladder cancer mortality in arsenic-exposed region II of Chile from 1950 to 2000. Am J Epidemiol 2007;166:1381–91.

Zhang GF, Xie SD, Ho YS. A bibliometric analysis of world volatile organic compounds research trends. Scientometrics 2010;83:477–92.