Original Research Article

A Bibliometric Analysis of Publications on Drinking Water Research in India

Abstract

Every creature on this planet needs water to survive and water is one of the most significant natural resources. A moderate attempt has been made in this study to understand the research trends in drinking water in India during the period of 1990 – 2019, based on Science Citation Index Expanded the Web of Science Core Collection by Clarivate Analysis. A total 74,277 documents were found, of which 68,029 research articles, in that 2903 articles were drinking water publications relating to India. The results indicated that the annual number of research articles have increased from about eight articles in early years 1990 to 269 articles in the latest year 2019. Also out of 2903 drinking water articles 2306 (79%) were country independent articles and 597 (21%) articles were internationally collaborative articles with 104 countries. The researchers used top three Web of Science categories 'environmental sciences', 'water resources' and 'toxicology'. The study found that the *Environmental Monitoring and Assessment* was the most productive journal and Indian Institutes of Technology was the most productive institution among top ten most productive institutions in India.

Keywords: Scientometrics, SCI-EXPANDED, India, Drinking water, Environmental science

1. Introduction

Water is important natural resource for sustaining life and the environment. Water is crucial for life and key to the survival of any species on earth, not only for human beings but also for all animals and plant species present on the earth[21]. We have always thought that water is available in abundance and the gift of nature. Water comprises from 75% body weight in babies to 55% in elders and is crucial for cellular homeostasis and life[52].

However, the phenomenal population growth has intensifying pressure on every natural resource to meet the demand of the world's ever-growing population, especially in Asia, particularly in India[72]. With the advent of the green revolution technologies, India has increased the consumption of fertilizer from 0.3 million metric tons in 1961 to 18.7 million metric tons in 2000, which resulted in a 170% increase in food grain production[18]. So that in India, over the past few decades not only the ever-growing population but also due to the urbanization, industrialization and unjudicial use of water resources has led to the degradation of water quality and reduction in per capita availability of safe drinking water[2]. The presence of various hazardous contamination like fluorides, arsenic, nitrate, sulphate, pesticides, other heavy metals, etc. in drinking water has been reported from different parts of India[60].

In India, the priority research areas in developing counties are concerned with easement of disease burden, mitigating water scarcity, and enhancing food security[62]. Particularly drinking water research continues to attract huge interest from researchers[16]. This has lead to a surge in publication output in this area, especially in recent years[37]. In general, drinking water research is diverse, ranging from such aspects as hydrogeochemistry[22], availability assessments[66], quality assessments[9] and treatment to policy and management issues. To facilitate progress in drinking water research in India, there is a need to consolidate the divergent knowledge base to focus India's research efforts in the disciplines.

Attempts towards this desired data integration include several reviews by Indian researchers[4][3][64]. While systematic literature reviews are used in interrogating research and policy issues in the subsequent periods, such reviews address only a limited scope of data and are unhelpful in consolidating divergent data in the open research fields like drinking water and even more so if the field of study is multidisciplinary with authorship that different socio-political and academic borders.

For hundreds of years, drinking water-related research has become a multidisciplinary field which covers a wide spectrum, including studies on environmental sciences[43][78], biochemistry and molecular biology[5] and medicine research[48]. Bibliometric studies are based on quantitative statistical examination of publication trends, anchored on word cluster, and distribution of terms in article title, author keywords and keywords plus, among other indicators[19][42].

Bibliometrics is a tool that allows researchers or authors to analyze, interpret and improve indicators on the dynamics of scientific publications on a particular topic[75]. This bibliometric analysis provides the characteristics of the existing literature on a topic that helps future research directions, improves decision-making, and minimises errors[76][14]. It refers to the research methodology harnessed in the library and Information Sciences, which utilizes quantitative analysis and statistics to describe distribution patterns of publications within a particular topic field, institution and country[65]. Bibliometric analysis has been more used to evaluate the research performance in many fields such as occupational therapy[7], Adsorption Research[20], Drinking Water[19], Molecular Biology[26], Chemical Engineering[27], Materials Science[29], Algal – Bacterial Symbiotic in wastewater treatment[31], Neurotoxicity of nanoparticles[32], Metal-organic frameworks[34], dengue[36].

Hence the purpose of this study is to bibliometrically analyse the literature of Indian researches on drinking water which was listed in the Science Citation Index Expanded (SCI-EXPANDED), the Web of Science (WoS) core collection by clarivate analytics during the period from 1990 to 2019. The analysis included document type and language publications, collaborative countries, institutions and authors. This study has also analysed the top ten most frequently cited drinking water articles by India and research focus and their development trends.

2. Methods

Data were retrieved on October 31, 2020, from the Science Citation Index Expanded (SCI-EXPANDED), the Web of Science Core Collection by Clarivate Analytics. According to Journal Citation Reports (JCR), it indexed 9,370 journals with citation references across 178 Web of Science categories in SCI-EXPANDED in 2019. The terms "drinking water", "drinking waters", "drinkable water", "drinkable waters", and "drinking waterborne"[19] were searched in terms of topic (including title, abstract, authors' keywords, and *KeyWords Plus*) within the publication years ranging from 1990 to 2019. It has resulted 74,277 documents including 68,029 articles. The results then, refined by countries/regions of India. It has resulted 4,263 documents (5.7% of the 74,277 documents) including 3,917 articles (5.8% of the 68,029 articles). Recently, Ho pointed out that high percentage documents searched out by the terms of topic in Web of Science Core Collection were inappropriate in a bibliometric topic[31][32]. In 2012, a filter named 'front page' including document title, abstract, and author keywords was proposed to improve the searching method in bibliometric studies by Ho's group[20]. The 4,263 documents were downloaded into spreadsheet software, and additional coding was manually performed using Microsoft Excel 2016 for analysis[45][34]. After checking publication year and using the 'front page' as filter, 3,128 documents (73% of the 4,263 documents) including 2,903 articles (74% of the 3,917 articles) were drinking water publications in by at least one affiliation in India. Besides, the journal impact factor (IF_{2019}) of each journal was obtained from the JCR in 2019. The affiliation of England, Scotland, Northern Ireland, Wales, and Anguilla has been reclassified as from the United Kingdom (UK).

In the SCI-EXPANDED database, the corresponding-author is labeled as reprint author, but in this study, we used the term corresponding-author[27]. In a single institutional article, the institution is classified as the first-and the corresponding-author institution[29]. In multi corresponding-author articles, only the last corresponding-author, institute, and country were considered[33]. In a single-author article where authorship is unspecified, the single-author is both the first and corresponding-author[29]. In single-author articles with multi affiliations, only the India institutes or the last institute and country were considered.

Three citation indicators to investigate the citations received by the publications were:

C_{year}: the number of citations from the Web of Science Core Collection in a particular year. C_{2019}: means the number of citations in 2019[27].

TC_{year}: the total number of citations from the Web of Science Core Collection since publication year to the end of the most recent year. In this study, this is 2019 (TC_{2019})[80][13].

CPP_{year}: citations per publication ($CPP_{2019}=TC_{2019}/TP$), TP: total number of articles[27].

3. Results and Discussion

3.1. Document type and language of publication

Table 1. Citations and authors according to the document type

Document type	TP	%	AU	APP	TC_{2019}	CPP_{2019}
Article	2,903	93	13,469	4.6	54,178	19
Review	172	5.5	677	3.9	11,647	68
Proceedings paper	70	2.2	282	4.0	1,939	28
Meeting abstract	17	0.54	89	5.2	14	0.82
Editorial material	11	0.35	23	2.1	37	3.4
Letter	11	0.35	26	2.4	53	4.8
Note	8	0.26	24	3.0	69	8.6
Correction	5	0.16	32	6.4	1	0.20
Book chapter	4	0.13	14	3.5	37	9.3
Retracted publication	2	0.064	6	3.0	6	3.0
News item	1	0.032	1	1.0	0	0

TP: total number of publications; *AU*: number of authors; *APP*: number of authors per publication; TC_{2019}: the total number of citations from Web of Science Core Collection since publication year to the end of 2019; CPP_{2019}: number of citations (TC_{2019}) per publication (*TP*).

Comparing the total citations of documents in the Web of Science Core Collection, a better citation indicator, TC_{year} is proposed as a repeatable and checkable scientific data[80][13], and it is widely used in bibliometric research in the last decade[30][35]. The relationship among document types and their citations per publication, CPP_{year}, and the number of authors per publication, *APP*, has recently been proposed in a table[58]. Eleven document types indexed by the Web of Science were found (**Table 1**). The document type of articles was the most popular, with a total of 2,903 articles (93% of 3,128 documents), the number of authors per publication is 4.6. The largest number of authors in an article is “Global, regional, and national comparative risk assessment of 84 behavioural, environmental and occupational, and metabolic risks or clusters of risks for 195 countries and territories, 1990-2017: A systematic analysis for the Global Burden of Disease Study 2017”[73] published by 1,042 authors from 621 institutes in 91 countries. The document type of the reviews had the highest CPP_{2019} of 68, which can be attributed to the only classic review with TC_{2019} of 1,000 or more[47], titled “Arsenic removal from water/wastewater using adsorbents: A critical review”[56] by Dinesh Mohan and Charles U. Pittman Jr. with TC_{2019} of 599, 451, and 2,027. In addition, the five of the top ten publications were reviews by Mohan and Pittman (2007), Ayoob and Gupta (2006) with TC_{2019} of 670 (rank 2nd), Kabra *et al.* (2004) with TC_{2019} of 461 (rank 5th), Mohapatra *et al.* (2009) with TC_{2019} of 420 (rank 6th), and Pradeep and Anshup (2009) with TC_{2019} of 411 (rank 8th). The CPP_{2019} of the reviews was 3.6 times than the CPP_{2019} of the articles. A total of 172 reviews were published widely in 113 journals. It should be pointed out that in the Web of Science Core Collection, documents can be divided into two types of documents. For example, 70 documents were classified as document types of proceedings papers and articles, thus the sum of the percentages is greater than100%[75].

Only document-type articles were used for further analysis because it contains complete research ideas such as introduction, methods, results, discussions, and conclusions. The only non-English article titled “Case-controlled cohort health indicator study of an integrated fluorosis mitigation program in India”[24] was published in Spanish.

3.2. Characteristics of publication outputs

In order to understand publications and their impact trends in a research topic, a relationship between the annual number of articles (*TP*) and their citations per publication ($CPP_{year}=TC_{year}/TP$) by the years was proposed by Ho (2013).

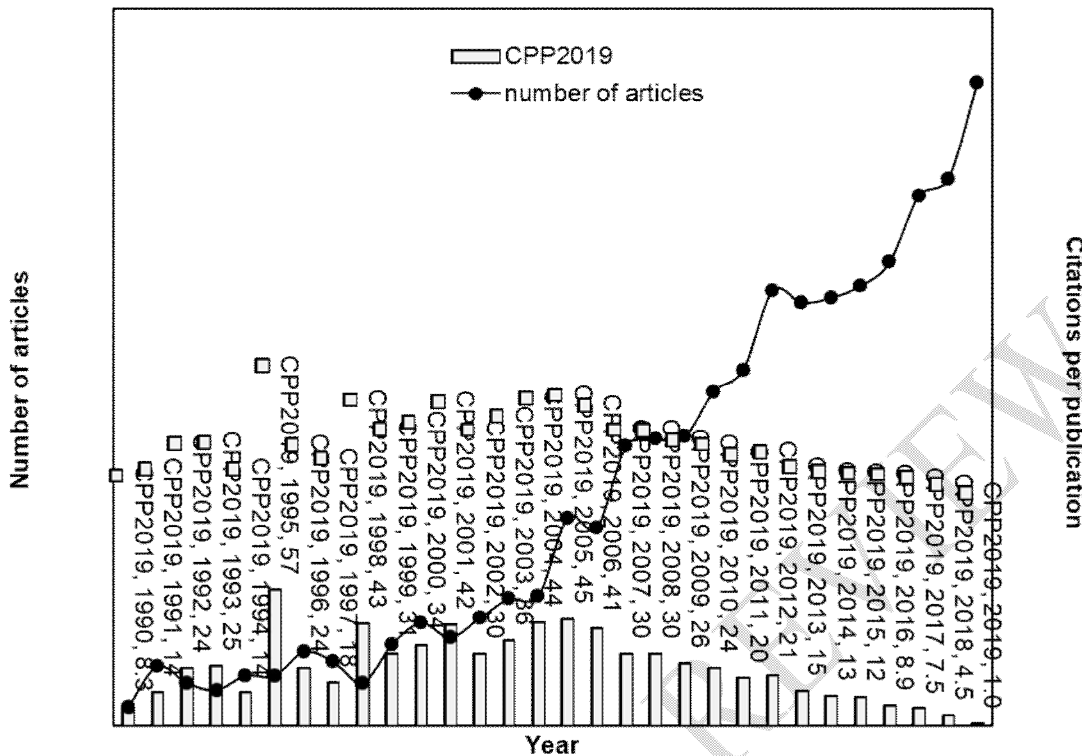

Figure1. The number of articles and citations per publication by year.

The relationship is shown in fig 1. The annual number of articles (TP) increased from about 8 articles in the early years 1990s to 269 articles in the latest years 2019. The exponential increase in the research articles on drinking water due to increase in the awareness of information technology[70]. Which would have helped data handling and transmission and assess to scientific information during 1990 to 2018[77]. The period under study also coincided with increased support of the Indian Government to undertake research on drinking water.

From Fig 1 it is cleared that drinking water research in India is a developing study field. A similar trend in research is also reported in Africa[77].

Figure 1 also shows that the mean citations were not constant, and the highest average number of citations (CPP=57) was observed for the articles published in the year 1995. It is observed that the citations during the initial years from 1990 to 1994 published would likely to fluctuate more because some publications did not start to accumulate citations until a few years after publication. Articles published after 2005 showed that CPP was decreasing in the recent years articles did not get the more citations due to shorter time[34].

3.3. Web of Science categories and journals

Journal Citation Reports (JCR) indexed 9,370 across 178 Web of Science categories in SCI-EXPANDED in 2019. A total of 2,903 drinking water articles published by India in SCI-

EXPANDED were published in 785 journals which are classified among the134 Web of Science categories in SCI-EXPANDED. Altogether, 187 articles published in 71 journals were not in SCI-EXPANDED in 2019 without IF_{2019}. **Table 2** shows the top 12 productive Web of Science categories with more than 100 articles. A total of 1,320 articles (45% of 2,903 articles) were published in the top three categories: environmental sciences (820 articles; 39% of 2,903 articles), water resources (395; 14%), and toxicology (393; 14%). Development trends of categories in a research topic were compared using a figure[19].

Table 2. The top 12 productive Web of Science categories with TP> 100

Web of Science category	*TP* (%)	APP	CPP_{2019}	No.*J*
environmental sciences	820 (28)	4.3	20	265
water resources	395 (14)	3.9	15	94
toxicology	393 (14)	4.5	26	92
public, environmental and occupational health	262 (9.0)	5.5	23	193
environmental engineering	240 (8.3)	4.3	28	53
multidisciplinary chemistry	213 (7.3)	3.7	9.4	177
chemical engineering	196 (6.8)	3.9	24	143
multidisciplinary geosciences	192 (6.6)	3.8	14	200
pharmacology and pharmacy	173 (6.0)	4.4	27	270
biochemistry and molecular biology	146 (5.0)	4.2	22	297
analytical chemistry	129 (4.4)	4.4	19	86
multidisciplinary sciences	108 (3.7)	4.3	11	71

TP: number of publications; *APP*: number of authors per publication; CPP_{2019}: number of citations (TC_{2019}) per publication (*TP*); No.*J*: number of journals in a Web of Science category.

It should also be noticed that journals could be classified in two or more categories in the Web of Science Core Collection, for instance, *Environmental Earth Sciences* was classified in environmental sciences, multidisciplinary geosciences, and water resources, and thus the sum of percentages was higher than 100%[29]. Compare the top 12 categories, articles published in the category of environmental engineering had the highest CPP_{2019} of 28, followed by pharmacology and pharmacy with CPP_{2019} of 27, and toxicology CPP_{2019} of 26, while articles published in multidisciplinary chemistry had a CPP_{2019} of 9.4. Articles published in category of public, environmental and occupational health had the highest *APP* of 5.5 while articles published in multidisciplinary chemistry had an *APP* of 3.7.

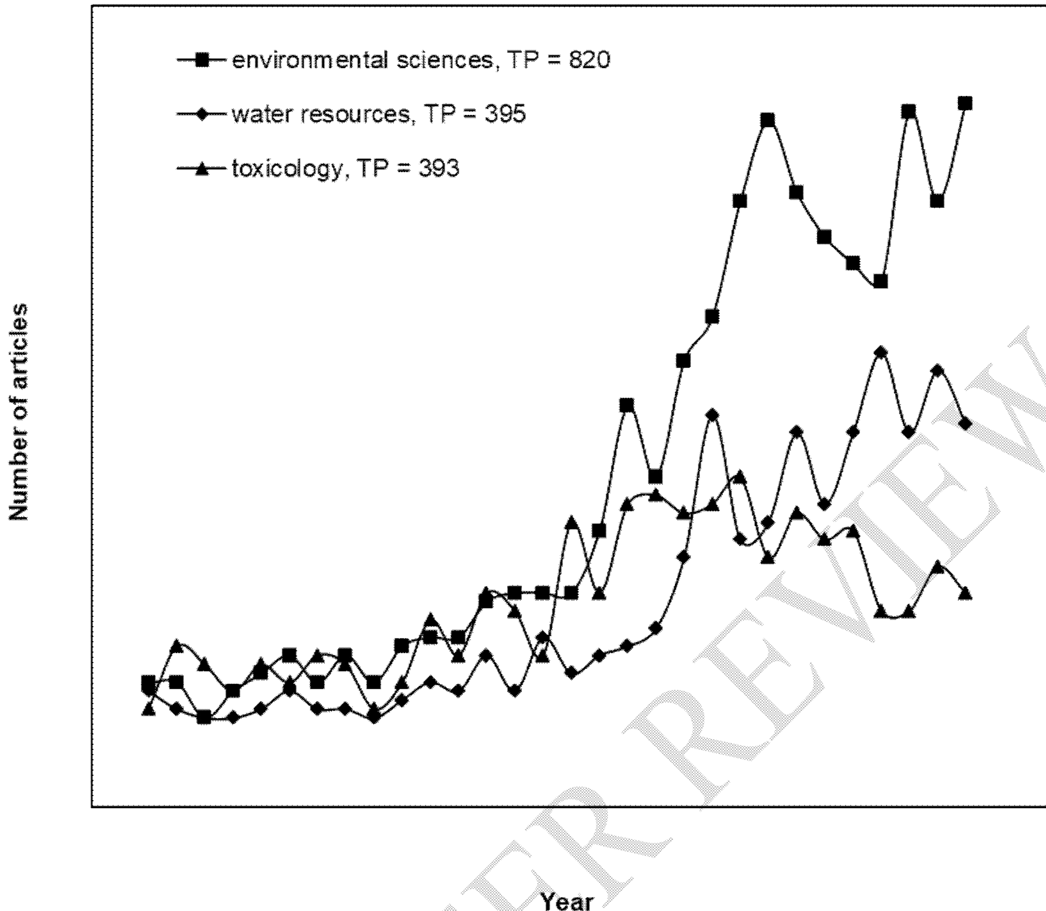

Figure 2. Development of the top three categories

The development of the top three categories was illustrated in Fig. 2. The total number of publications per year from the three categories with more than 300 articles. Among top three categories ‘environmental sciences’ contributed most with 820 publications followed by ‘water resources’ (TP= 395) and ‘toxicology’ (TP= 393) Number of publications readily showed that (fig 2), there is steady development with no period of rapid growth in all three categories up to 2005. After the 2005 environmental science category entered the phase of rapid growth up to 2019, the other categories showed little growth. The environmental sciences category is a broad and multidisciplinary science; hence there are more number of publications in this area as it covers Ecology, Wastes, Environmental Management, Forestry and Environment, Water Pollution, Nature and Natural Resources Conservation, Air Pollution, Wildlife and Plants and Pollution. While publications on drinking water research are less in the toxicology category as few national institutes are working on it in India[40].

Table 3.The top10 productive journals

Journal	*TP*(%)	IF_{2019}	APP	CPP_{2019}	Web of Science category
Environmental Monitoring and Assessment	107 (3.7)	1.903	3.7	23	environmental sciences
Fluoride	67 (2.3)	1.000	3.5	21	public, environmental and occupational health toxicology
Environmental Earth Sciences	58 (2.0)	2.180	3.8	12	environmental sciences multidisciplinary geosciences water resources
Environmental Science and Pollution Research	46 (1.6)	3.056	4.5	14	environmental sciences
Desalination and Water Treatment	45 (1.6)	0.854	3.4	4.0	chemical engineering water resources
Current Science	44 (1.5)	0.725	3.4	11	multidisciplinary sciences
Journal of the Geological Society of India	42 (1.4)	0.899	3.6	5.0	multidisciplinary geosciences
Biological Trace Element Research	37 (1.3)	2.639	3.8	13	biochemistry and molecular biology endocrinology and metabolism
Journal of Hazardous Materials	34 (1.2)	9.038	3.9	62	environmental engineering environmental sciences
RSC Advances	31 (1.1)	3.119	3.9	11	multidisciplinary chemistry

TP: number of publications; IF_{2019}: journal impact factor in 2019; *APP*: number of authors per publication; CPP_{2019}: number of citations (TC_{2019}) per publication (*TP*).

The top 10 most productive journals are listed in **Table 3** with journal impact factor (IF_{2019}), number of authors per publication (*APP*), number of citations per publication (CPP_{2019}), and Web of Science category. Four of the 10 journals were classified in the category of environmental sciences. *Environmental Monitoring and Assessment* published the most articles (107 articles; 3.7% of 2,903 articles). Compare the articles published in the top 10 journals; articles published in *Environmental Science and Pollution Research* had the highest *APP* of 4.5 while *Desalination and Water Treatment* and *Current Science* had an *APP* of 3.4, respectively. Articles published in *Journal of Hazardous Materials* had the highest CPP_{2019} of 62 which can be attributed to the highly cited article with TC_{2019} of 100 or more[29], titled "Fluoride in drinking water and its removal"[55] by Meenakshi and Maheshwari from the Indian Institute of Technology with TC_{2019} of 475. Besides, according to the journal impact factor, *Lancet* with one article, places first with the highest IF_{2019} of 60.392, followed by *Nature Reviews Disease Primers* with one article (IF_{2019}=40.689), and *Advanced Materials* with one article(IF_{2019}=27.398).

3.4. Collaborative countries, institutions, and authors

Table 4.Top 10 most collaborative countries

Country	CP	CPP_{2019}	*CPR*(%)	*FPR*(%)	*RPR*(%)
USA	213	30	1 (7.3)	1 (3.7)	1 (3.8)
UK	52	24	2 (1.8)	2 (0.83)	2 (0.80)
Germany	46	23	3 (1.6)	3 (0.59)	3 (0.52)
Australia	35	27	4 (1.2)	8 (0.28)	7 (0.35)
Sweden	34	43	5 (1.2)	4 (0.41)	4 (0.45)
Canada	30	26	6 (1.0)	5 (0.38)	8 (0.31)
Japan	29	35	7 (1.0)	6 (0.34)	8 (0.31)
South Korea	28	18	8 (1.0)	8 (0.28)	10 (0.28)
Saudi Arabia	27	17	9 (0.93)	18 (0.10)	27 (0.035)
China	24	21	10 (0.83)	6 (0.34)	5 (0.38)

CP: total number of internationally collaborative articles; CPP_{2019}: citations per publication (TC_{2019}/CP); *CPR*(%): the rank and the percentage of internationally collaborative articles in the total India articles; *FPR*(%): the rank and the percentage of first-author articles in the total first-author articles; *RPR*(%): the rank and the percentage of the corresponding-author articles in the total corresponding-author articles.

In India, 2,306 drinking water articles (79% of 2,903 articles) were country independent articles and 597 (21%) were internationally collaborative articles with 104 countries. The three publication indicators: internationally collaborative articles (*CP*), first-author articles (*FP*), and corresponding-author articles (*RP*) as well as citation indicator, CPP_{2019} were applied to compare the top 10 collaborative countries **(Table 4)**. Four Asia countries, three European countries, two American countries, and one Oceania country were ranked on the top 10 of collaborative with India. South Africa with 20 articles ranked 12^{th}, was the most collaborative country in Africa. The USA ranked the top in the three publication indicators with *CP* of 213 collaborative articles (7.3% of 2,903 articles), *FP* of 107 articles (3.7% of 2,903 first-author articles), and *RP* of 110 articles (3.8% of 2,884 corresponding-author articles). Articles collaborative with Sweden had the highest CPP_{2019} of 43 while articles collaborative with Saudi Arabia had a CPP_{2019} of 17. Three of the 69 highly cited articles by Stanaway *et al.* (2018) with CPP_{2019} of 245, Kumar *et al.* (2007) with CPP_{2019} of

128, and Mahata *et al*. (2003) with CPP_{2019} of 109, were collaborative with Sweden.

Table 5. Top 10 productive institutions

Institute	TP	TP *R* (%)	IP *R* (%)	CP *R* (%)	FP *R* (%)	FP CPP_{2019}	RP *R* (%)	RP CPP_{2019}	SP *R* (%)	SP CPP_{2019}
Indian Institutes of Technology	138	1 (4.8)	1 (5)	1 (4.5)	1 (3.3)	50	1 (3.5)	49	13 (1.1)	5.0
Jadavpur University	107	2 (3.7)	2 (2.9)	1 (4.5)	2 (2.6)	35	2 (2.7)	35	1 (6.4)	16
Bhabha Atomic Research Center	83	3 (2.9)	3 (2.8)	4 (2.9)	6 (1.7)	9.6	5 (1.7)	10	13 (1.1)	9.0
University of Madras	72	4 (2.5)	6 (2.5)	10 (2.4)	4 (1.9)	32	4 (1.9)	32	13 (1.1)	5.0
Panjab University	71	5 (2.4)	7 (2.3)	6 (2.6)	3 (2)	14	3 (2)	14	N/A	N/A
Anna University	64	6 (2.2)	12 (1.5)	4 (2.9)	11 (1.2)	13	10 (1.3)	13	N/A	N/A
Jawaharlal Nehru University	61	7 (2.1)	9 (1.7)	9 (2.5)	10 (1.3)	21	10 (1.3)	22	4 (3.2)	13
Council of Scientific and Industrial Research (CSIR)	60	8 (2.1)	11 (1.6)	8 (2.6)	9 (1.3)	26	9 (1.4)	25	5 (2.1)	12
Indian Veterinary Research Institute	60	8 (2.1)	12 (1.5)	6 (2.6)	12 (1.1)	19	12 (1.1)	19	N/A	N/A
Industrial Toxicology Research Centre	57	10 (2)	5 (2.6)	16 (1.3)	5 (1.7)	23	6 (1.6)	25	13 (1.1)	6.0

TP: total number of articles; *TPR*(%): the rank and the percentage of total articles in the total number of articles; *IPR*(%): the rank and the percentage of institutional independent articles in the total institutional independent articles; *CPR*(%): the rank and the percentage of inter-institutionally collaborative articles in the total inter-institutionally collaborative articles; *FPR*(%): the rank and the percentage of first-author articles in the total first-author articles; *RPR*(%): the rank and the percentage of the corresponding-author articles in the total corresponding-author articles; *SPR*(%): the rank and the percentage of the single-author articles in the total single-author articles; *CPP*(CPP_{2019}): number of citations (TC_{2019}) per publication (*TP*); N/A: not available.

In total, 1,465 articles (50% of 2,903 articles) were institute independent articles and 1,438 (50%) were inter-institutionally collaborative articles. The six publication indicators[34]: total number of articles (*TP*), institutional independent articles (*IP*), inter-institutionally collaborative articles (*CP*), first-author articles (*FP*), corresponding-author articles (*RP*), single-author articles (*SP*) as well as citation indicator CPP_{2019} were applied to compare the top 10 institutions **(Table 5).** Five of the top 10 institutions were universities and other five were research centres. Indian Institutes of Technology took the leading position for the five publication indicators with *TP* of 138 articles (4.8% of 2,903 articles), *IP* with 73 articles (5.0% of 1,465 institutional independent articles), *CP* of 65 articles (4.5% of 1,438 inter-institutionally collaborative articles), *FP* of 97 articles (3.3% of 2,903 first-author articles), *RP* of 101 articles (3.5% of 2,884 corresponding-author articles). Jadavpur University, Andhra University, and Government Meera Girls College ranked the top in the single-author articles with *SP* of six articles (6.4% of 94 single-author articles) respectively. Panjab University, Anna University, and Indian Veterinary Research Institute had no single-author articles. Compare the top10 productive institutes, articles published by the Indian Institutes of Technology as the first-author and the corresponding-author had the highest CPP_{2019} of 50 and 49, respectively. The most frequently cited drinking water article in India was an institutional independent article by Jain and Pradeep from the Indian Institutes of Technology[38]. Articles published by Jadavpur University as single-author had the highest CPP_{2019} of 16. However, a bias appeared because the Indian Institute of Technology have branches in many different cities[74]. At present, the articles of this institute were pooled as one heading, and articles divided into branches would result in different rankings.

In experimental science, the accepted convention is that the most important positions are first and last, and these positions are usually the corresponding author[83][15]. The first-author is that person who contributed most to the work, including conducting research and writing of the manuscript[67][26]. The corresponding-author is perceived as the author contributing significantly to the article independently of the author position[53].The corresponding-author supervised the planning and execution of the study and the writing of the paper[8]. In 2012, Ho proposed an indicator; the *Y*-index is related to the number of first-author publications (*FP*) and corresponding-author publications (*RP*). The*Y*-index combines two parameters (*j*,*h*), to evaluate the publication potential and contribution characteristics as a single index. This indicator has been used to compare authors in a research topic: metal-organic frame works[79] and occupational therapy[7].

The *Y*-index is defined as[27][29]

$$j = FP + RP \quad (1)$$

$$h = \tan^{-1}\left(\frac{RP}{FP}\right) \quad (2)$$

Where *j* is the publication potential, a constant related to publication quantity; and *h* is publication characteristics which can describe the proportion of *RP* to *FP*. The greater the value of *j*, the more the contribution of the first-and corresponding-author articles. Different values of *h* represent different proportions of corresponding-author articles from first-author articles.

$h=\pi/2$, indicates only corresponding-author articles, *j* is the number of corresponding-author articles;

$\pi/2 > h > 0.7854$ indicates more corresponding-author articles;

h=0.7854 indicates the same number of first-and corresponding-author articles;
0.7854>h>0 indicates more first-author articles;
h=0, indicates only first-author articles, j is the number of first-author articles.

In total, 2,814 (97% of 2,903 articles) drinking water articles by India in the SCI-EXPANDED with both first-and corresponding-author information were selected to calculate *Y*-index for the authors. A total of 2,814 articles were published by 7,809 authors in which 5,241authors (67% of 7,809 authors) had no first-nor corresponding-author articles with *Y*-index=(0,0); 647 (8.3%) authors published only corresponding-author articles with $h=\pi/2$; 141 (1.8%) authors published more corresponding-author articles with $\pi/2>h>0.7854$; 747 (9.6%) authors published the same number of first-and corresponding-author articles with h=0.7854; 93 (1.2%) authors published more first-author articles with 0.7854>h>0; and 940 (12%) authors published only first-author articles with h=0.

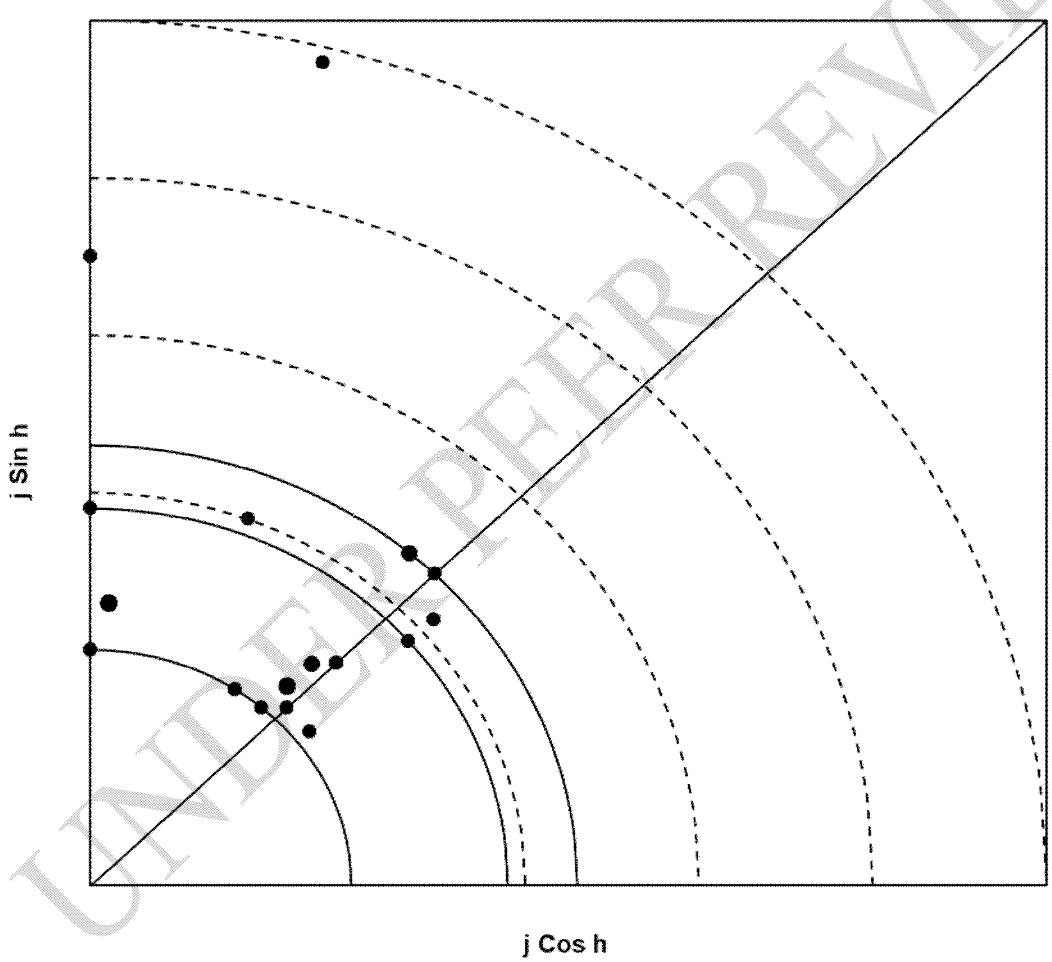

Figure 3. Distribution of the top19 authors with their *Y*-index values (*j*≥15)

Figure 3 shows distribution of the *Y*-index (j,h) of the top 19 authors with j≥15. Each dot represents one value of the *Y*-index (j,h) that could be one author or many authors[30],for example M. Kumar and N.S. Raowith *Y*-index = (20, 0.7854). S.J.S. Flora had the highest j of 54 with *Y*-index= (54, 1.320). Flora published 44 articles including 11 first-author articles and 43 corresponding-author articles. D.K. Dhawan ranked second with a j of 40. Dhawan published only

40 corresponding-author articles with *Y*-index= (40, π/2). S.N. Sarkar (15, π/2), S. Singh (15, 0.9828), and P.W. Ramteke (15, 0.8520) had the same publication potential with *j* of 15 for all. It is clear that all these authors are located on the same curve (*j*= 15) in **Fig. 3**, indicating that they have different publication characteristics. Sarkar published only corresponding-author articles with *h* of π/2, followed by Singh published seven first-author articles and eight corresponding-author articles with *h* of 0.9828, and Ramteke published five first-author articles and nine corresponding-author articles with *h* of 0.8520. Similarly, A.K. Giri (24, π/2) and A. Biswas (24, 0.7023) are located on the same curve (*j*= 24). Giri has only 24 corresponding-author articles while Biswas has 13 first-author articles and 11 corresponding-author articles. S. Kumar (28, 0.8567) and S.L. Choubisa (28, 0.7854) are located on the same curve (*j*= 28). Kumar has a higher ratio of corresponding-author articles to first-author articles while Choubisa has a lower ratio of corresponding-author articles to first-author articles. These authors with the same value of *j* and different *h*, had the same potential to publish articles but totally different publication characteristics. Furthermore, S.L. Choubisa (28, 0.7854), M. Kumar (20, 0.7854), and S. Giri (16, 0.7854) are located on the same straight line (*h* = 0.7854), indicating that they have different publication potential but the same publication characteristics. Similarly, D.K. Dhawan (40, π/2), A.K. Giri (24, π/2), and S.N. Sarkar (15, π/2) are located on the same straight line (*h* = π/2). Dhawan had a higher publication potential with *j* of 40 followed by Giri with *j* of 24, and Sarkar with *j* of 15. However, it was pointed out that a bias in analysis of authorship might occur when different authors had the same name or one author used different names (eg. Maiden names) in their articles[82].

3.5. Top ten most frequently cited drinking water articles by India

The total number of citations of a document in the Web of Science Core Collection is updated from time to time. Ho's group proposed citation indicators TC_{year}[80] and C_{year} (Ho, 2012). The advantage of using TC_{year} and C_{year} is that they are immutable and ensure repeatability compared with the citation index of the Web of Science Core Collection[20]. Citation frequency is considered to reflect the impact of scientific publications, although not necessarily quality[6]. The best articles can be classified as articles that most researchers can read and cite in peer-reviewed journals[68]. **Table 6** listed the 10 most frequently cited articles with two citation indicators[27]. Two of the 10 articles were published in *Separation and Purification Technology* (IF_{2019}=5.774) and *Analyst* (IF_{2019}=3.978), respectively. Indian Institutes of Technology published the most of five articles, followed by Jadavpur University with three. D. Chakraborti published the most three articles. Citation history of the top 10 articles were presented in **Figs. 4 and 5**. An article impact might not be always high (Fu *et al.*, 2012; Ho, 2014a). Highly cited article by Chatterjee *et al.* (1995) had TC_{2019} of 413 ranked 3rd but had lower impact in 2019 with C_{2019} of 7 ranked 238th. Similarly, an article by Das *et al.* (1995) had TC_{2019} of 352 ranked 6th and C_{2019} of 10 ranked 128th. Although some recently published articles in the past few years have great potential, their TC_{2019} is not high. Therefore, articles that had an impact in 2019 are also concerned. An article titled "SERS and fluorescence-based ultrasensitive detection of mercury in water"[51] had TC_{2019} of 50 ranked 258th and C_{2019} of 32 ranked 8th.

Table 6. The top 10 most frequently cited articles

Rank (TC_{2019})	Rank (C_{2019})	Title	Country	Reference
1 (503)	4 (54)	Potential of silver nanoparticle-coated polyurethane foam as an antibacterial water filter	India	Jain and Pradeep (2005)
2 (475)	3 (62)	Fluoride in drinking water and its removal	India	Meenakshi and Maheshwari (2006)
3 (413)	238 (7)	Arsenic in ground water in six districts of West Bengal, India: The biggest arsenic calamity in the world. Part I. Arsenic species in drinking water and urine of the affected people	India	Chatterjee *et al.* (1995)
4 (391)	7 (33)	Equilibrium, kinetics and thermodynamic studies for adsorption of As(III) on activated alumina	India	Singh and Pant (2004)
5 (373)	9 (31)	Equilibrium, kinetics and breakthrough studies for adsorption of fluoride on activated alumina	India	Ghorai and Pant (2005)
6 (352)	128 (10)	Arsenic in ground water in six districts of West Bengal, India: The biggest arsenic calamity in the world. Part 2. Arsenic concentration in drinking water, hair, nails, urine, skin-scale and liver tissue (biopsy) of the affected people	India	Das *et al.* (1995)
7 (347)	27 (21)	Arsenic levels in drinking water and the prevalence of skin lesions in West Bengal, India	USA, India	Mazumder *et al.* (1998)
8 (302)	67 (13)	Adsorption of As(III) from aqueous solutions by iron oxide-coated sand	India	Gupta *et al.* (2005)
9 (294)	53 (15)	Arsenic groundwater contamination in Middle Ganga Plain, Bihar, India: A future danger?	India	Chakraborti *et al.* (2003)
10 (258)	11 (29)	Ratiometric detection of Cr^{3+} and Hg^{2+} by a naphthalimide-rhodamine based fluorescent probe	India, Italy	Mahato *et al.* (2012)

TC_{2019}: the total number of citations from Web of Science Core Collection since publication year to the end of 2019; C_{2019}: the number of citations of an article in 2019 only.

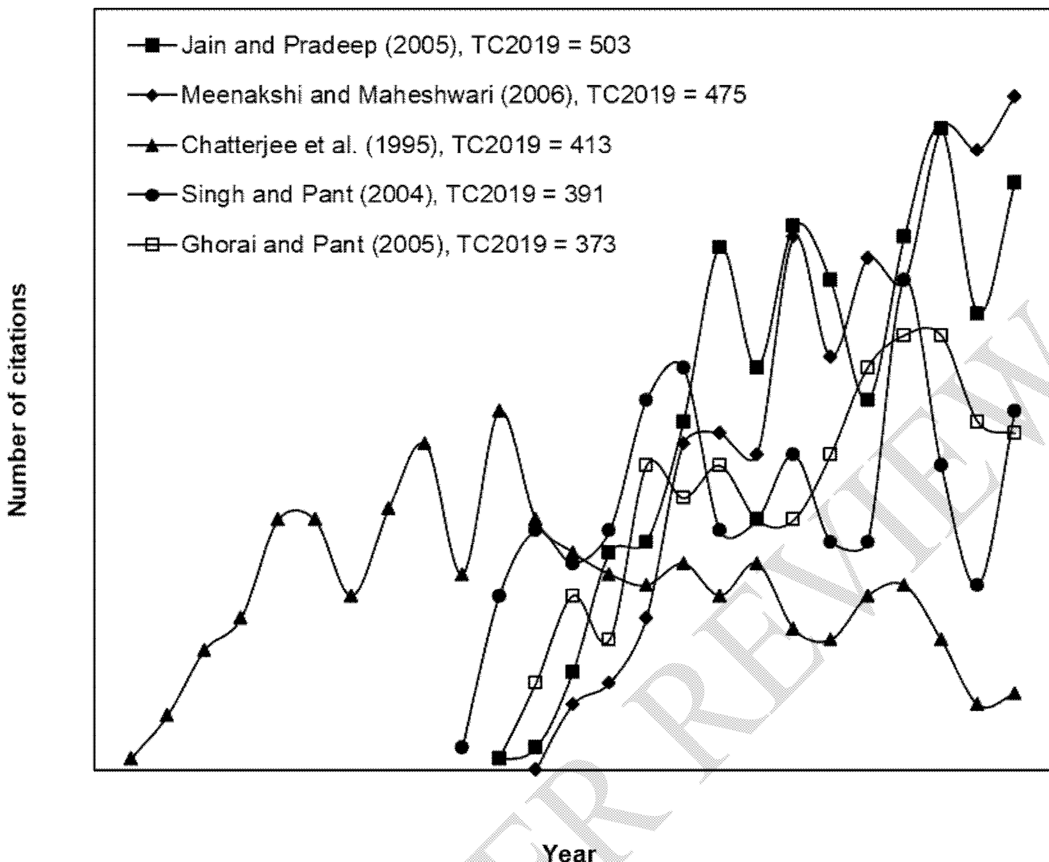

Figure 4.The citation history of the top five most frequently cited articles.

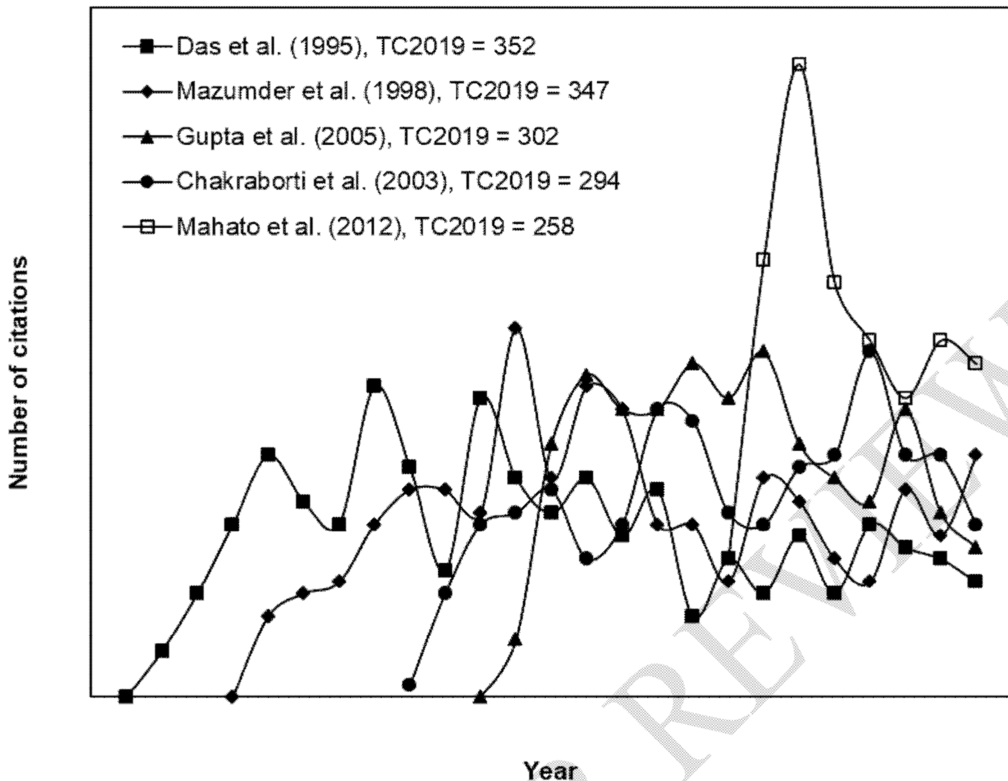

Figure 5.The citation history of the top 6 to 10 most frequently cited articles.

3.6. Research focuses and their development trends

Ho's group proposed distribution of words in article titles, abstracts, author keywords, and *Key Words Plus* in different periods as information to evaluate main research focuses and find their development trends in research topics[81][79].The results of keyword analyses provide information about the main and possible research foci as each word cluster comprised several supporting words. Thus, the development of the five major pollutants in drinking water research in India was found.

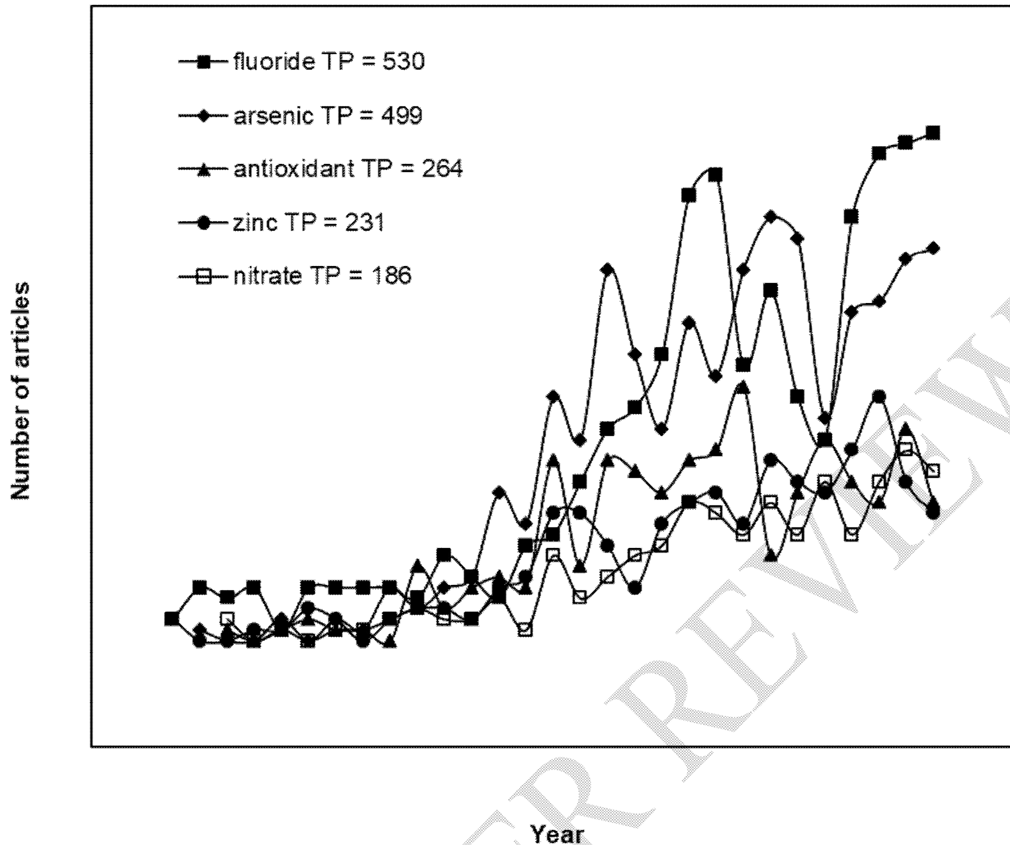

Figure 6. Development trends of the five main pollutants

Figure 6 shows the development of the five pollutants with supporting keywords as follows:

Fluoride: fluoride, fluoride, and fluorotic
Arsenic: arsenic, arsenic, arsenite, arsenate, and arsenical
Antioxidant: antioxidant, antioxidant, and antioxidants
Zinc: zinc, zinc, Zn, Zn^{2+}, and Zn (II)
Nitrate: nitrate, nitrate, nitrates
Uranium: uranium, uranium, U, and U (VI)

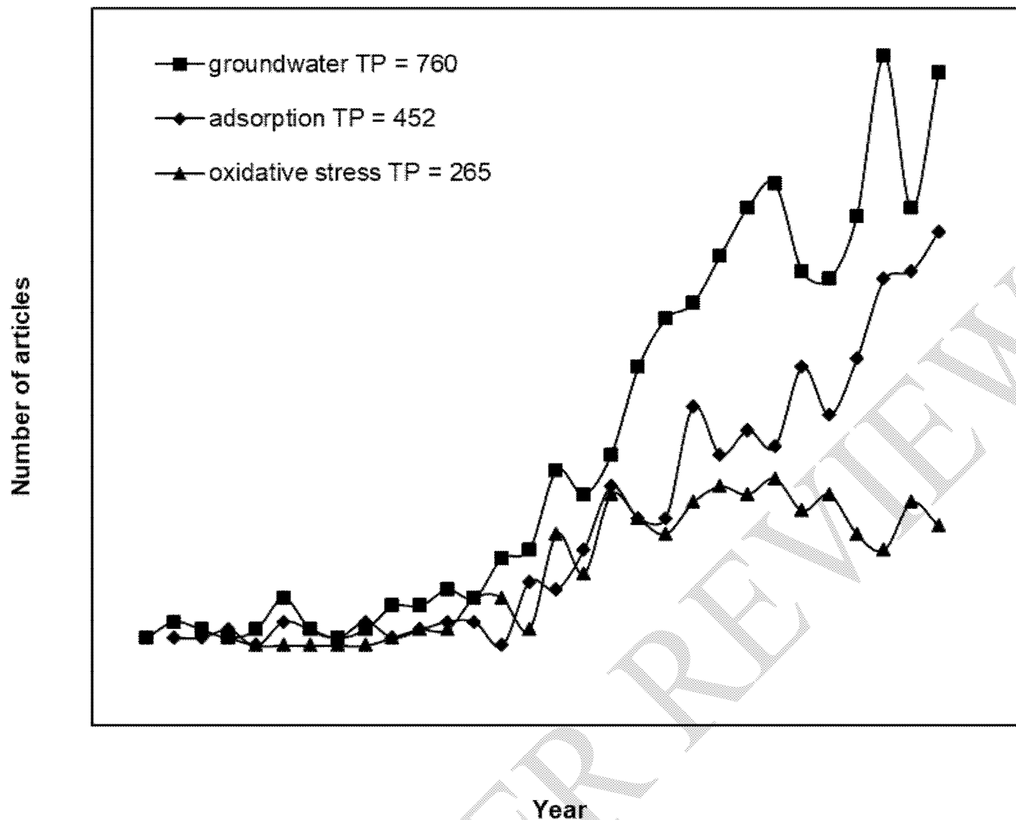

Figure 7. Development trends of the three main topics

The possible research hot topics in drinking water research in India were "groundwater", "adsorption", and "oxidative stress" with the most articles. "Groundwater" (groundwater, ground waters, and groundwater), "Adsorption" (adsorption, sorption, and bio sorption), and "oxidative stress" (oxidative stress).The article number growth trends of the three different topics are compared in Fig. 7.

Conclusions

This research paper has analysed the publications on drinking water research in India listed in the Web of Science Core Collection from 1990 to 2019. We have observed that most of the publications were written in English. Totally 4263 documents were found, out of 3917 articles in that 2903 publications on drinking water research in India were published. It is found from the study that during the period 1990-2019, an exponential growth of publications in the field of drinking water. The Articles published before 2007 had higher annual citations per publication. Among 178 Web of Science categories, the most productive web of science subject categories of the study were 'environmental science', 'water resources' and 'toxicology'. *Environmental Monitoring and assessment* and *Fluoride* were the most productive journals. Among the countries collaborated the USA, UK and Germany were the most productive countries in drinking water research. Indian Institutes of Technology and Jadhavpur University were the high productive Indian institutions among Indian institutions.

The possible research hot topics in drinking water research in India were "groundwater", "adsorption", and "oxidative stress" with the most articles. This paper would be very useful to the researchers & scientists who would like to carry out the research in the field of drinking water, particularly in India.

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