2019

Global toxicology research output (2008-2017): A scientometric analysis

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Abstract

In this study, a scientometric analysis of the global toxicology research output during 2008-2017 was performed based on the data retrieved from the SCOPUS database. This study analyzes the global research output in toxicology research on different parameters including the growth, global publication share and rank, contribution of major subject areas, contribution and citation impact of the most productive authors, affiliations and journals. A total of 29374 papers were published during 2008-2017 on toxicology research. Top 10 countries contributed 85.68% share of total publications. The United States ranks first in terms of the number of publications with a global publication share of 35.84% and h-index of 166. Almost 46.03% of publications are in the field of pharmacology, toxicology and pharmaceutics. The United States Environmental Protection Agency registered the highest h-index of 75 among the top 15 affiliations. *Toxicological Sciences* was the top journal in terms of publication output (2272 publications) and registered the highest h-index of 102 with an average citation per publication of 29.51.

Keywords Toxicology research, Scientometric analysis, Citations, Research output

Abbreviations

TP Total publications

TC Total citations

ACPP Average citations per paper

RGR Relative growth rate

Dt Doubling time

Introduction

Toxicology is a field of science that involves the scientific study of the undesirable effects of drugs, agents, chemicals, and other substances, particularly on living organisms. Analysis of the research output in peer-reviewed journals, conference proceedings and books etc. serves as an indicator of scientific research activity around the world. The progress of scientific productivity in the toxicology field has been poorly explored to date, and a few reports have been published in the past based on the analysis of publication output in toxicology research. Afshari R. (2014) examined the research output of toxicology in the Asia Pacific region during1996 to 2013. Kaur H. and Gupta B.M. (2009) reported the scientometric profile of Indian scientific output in pharmacology, toxicology & pharmaceutics during 1998–2007 during 1998–2007. Zyoud S.H. et al. (2014) performed the bibliometric analysis of toxicology research productivity in Middle Eastern Arab countries during the period 2003-2012. Miró Ò. et al. (2009) examined the research trends in toxicology in European countries. Delirrad M. conducted a bibliometric analysis of toxicology publications of Turkey and Iran based on data retrieved from the web of science**.** The main purpose of the present analysis is to evaluate the global research trends in the field of toxicology as reflected in the publication output during 2008-2017. The present study has the following objectives (i) to study the global publication output in toxicology research (ii) to study the publication growth rate and impact, (iii) to study the distribution of publications by broad subject areas, (iv) to identify the contribution of top 15 most productive affiliations, authors and journals (v) to identify the highly cited papers in toxicology research.

Methodology

For the purpose of the study, the publication data related to toxicology research for the period 2008-2017 was retrieved from SCOPUS International Database [www.SCOPUS.com/search]. A search was carried out in the SCOPUS database search bar under the tab of “Article title, Abstract and Keywords” using the words “Toxicology” from the period 2008-2017. The retrieved data was exported to MS-excel in CSV format containing the citations and bibliometric information. The impact of publications was assessed using parameters such as h-index and average citation per paper (ACPP). ACPP was calculated by using the following formula

$$ACPP = \frac{\text{Total number of citations}}{\text{Total number of publications}}$$

The h-index (Hirsch, 2005) is defined as “A scientist has index h if h of his or her N_p papers have at least h citations each and the other (N_p – h) papers have ≤h citations each”.

The growth of publications in toxicology research was analysed by using parameters like relative growth rate (RGR) and doubling time (Dt). RGR and Dt in publications for the period 2008-2017 were measured by model developed by Mahapatra (1985). RGR is the increase in publications/pages per unit of time. RGR was calculated by using the following formula

$$RGR = (\ln N_2 - \ln N_1) / (t_2 - t_1)$$

where, N_2 and N_1 are the cumulative numbers of publications in the years t_2 and t_1.

Dt is the time required for publications to become double of the existing amount. Dt was calculated by using the following formula

$$Dt = 0.693 / R$$

Where, R is the relative growth rate over the specific period of interval

Results and Discussion

Global publication output and growth rate in toxicology research

Global publication output in toxicology research during the period 2008-2017 consists of 29,374 records, with an average publication per year of 2937 and annual mean relative growth rate of 0.29. Publication output was highest in the year 2017, at 3620 and lowest in the year 2008, at 2231. The RGR dropped from a value of 0.72 in 2008 to 0.13 in 2017. The corresponding Dt for years gradually increased from 0.96 in 2008 to 5.33 in 2017.

Table 1: Global publication output and growth rate in toxicology research during 2008-2017

Year	TP	Cumulative	Cited	% Cited	Un-cited	RGR	Mean RGR	Dt	Mean Dt
2008	2231	2231	1877	84.13	354		0.29		2.94

2009	2342	4573	1925	82.19	417	0.72		0.96	
2010	2695	7268	2225	82.56	470	0.46		1.51	
2011	2855	10123	2486	87.08	369	0.33		2.10	
2012	3129	13252	2669	85.3	460	0.27		2.57	
2013	2915	16167	2445	83.88	470	0.2		3.47	
2014	3097	19264	2381	76.88	716	0.18		3.85	
2015	3273	22537	2546	77.79	727	0.16		4.33	
2016	3217	25754	2455	76.31	762	0.13		5.33	
2017	3620	29374	2430	67.13	1190	0.13		5.33	

Publications can be categorized as articles, reviews, book chapters, conference papers etc. as shown in table 2. 67.31% publications were published as original article (19772 publications) followed by review papers, book chapters, editorials, conference paper, letter, erratum, book, notes, short survey and conference review with publication share ranging from 14.65 to 0.06%.

Table 2: Types of publications

Type of Publications	TP	Publication share (%)
Article	19772	67.31
Review	4304	14.65
Book Chapter	1873	6.38
Editorial	842	2.87
Conference Paper	806	2.74
Letter	423	1.44
Erratum	414	1.41
Book	352	1.20
Notes	308	1.05
Short Survey	257	0.87
Conference Review	17	0.06
Article in Press	3	0.01
Retracted	3	0.01

Most productive countries

Table 3 lists the top 10 most productive countries in toxicology research during 2008-2017. The total global research output in toxicology research during 2008- 2017 was 29374. The global publication share of the top 10 most productive countries during 2008- 2017 varies from 3.15 to 35.84%. The United States tops the list with a global publication share of 35.84%. China ranks second (with a publication share of 7.94%) followed by the United Kingdom, Germany, India, and Canada with publication share ranging from 7.92 to 4.66%, France, Italy, Japan and Switzerland ranks at 7th to 10th positions, with publication share ranging from 4.50 to 3.15 %, respectively. In terms of citation quality and impact, the global ACPP varies from 8.31 to 26.58 and h-index varies from 52 to 166 during 2008-2017. Switzerland registered the highest citation per publication with 26.58 citations per paper followed by United Kingdom (26.15 citations per publication), Italy (25.75 citations per publication), Canada (24.9 citations per publication) and Germany (24.34 citations per publication). The USA registered the highest h-index of h=166, followed by United Kingdom (h=105), Germany (h=100), and China (h=82).

Table 3: Top 10 most productive countries in toxicology research for the period 2008-2017.

S. no.	Country	TP	Publication share (%)	TC	ACPP	Cited	% cited	h-index
1	United States	10528	35.84	232281	22.06	9010	85.58	166
2	China	2333	7.94	41946	17.98	1843	79.00	82
3	United Kingdom	2326	7.92	60815	26.15	2046	87.96	105
4	Germany	2304	7.84	56084	24.34	1958	84.98	100
5	India	1537	5.23	12779	8.31	804	52.31	52
6	Canada	1368	4.66	34066	24.90	1208	88.30	77
7	France	1323	4.50	27041	20.44	1098	82.99	77
8	Italy	1303	4.44	33557	25.75	1178	90.41	80
9	Japan	1223	4.16	17579	14.37	1092	89.29	56
10	Switzerland	924	3.15	24558	26.58	828	89.61	71
	World	29374						

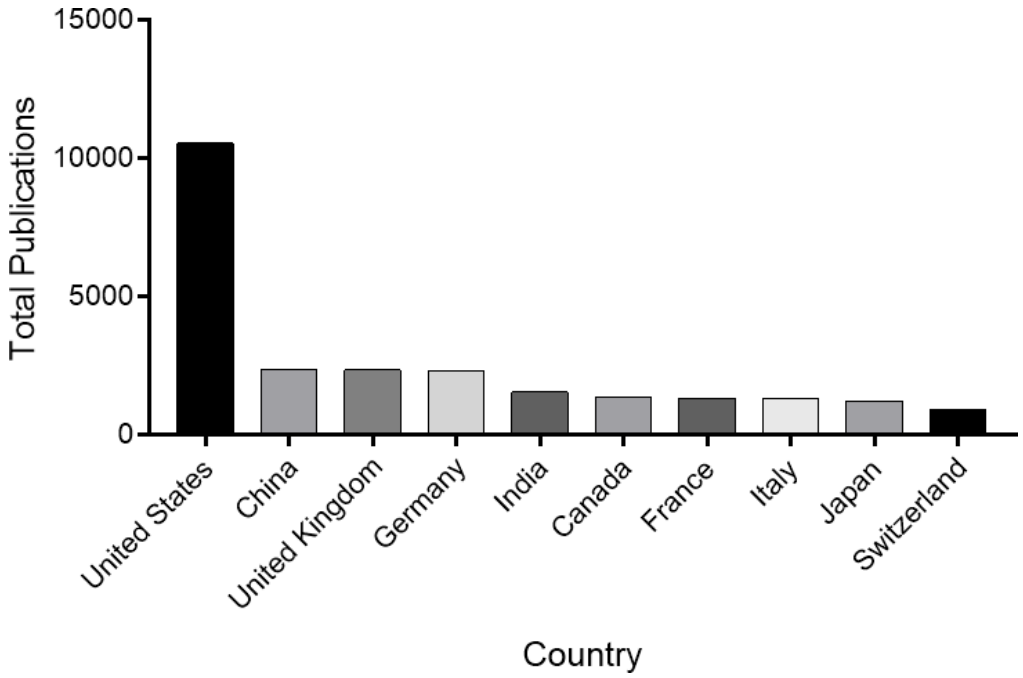

Figure 1. Most productive countries in toxicology research during 2008- 2017

Most productive subject areas

Top 10 most productive subject areas in toxicology research during 2008-2017 were pharmacology, toxicology and pharmaceutics (13522 publications), medicine (10333 publications), environmental science (7293 publications), biochemistry, genetics and molecular biology (5015 publications), chemistry (3008 publications), agricultural and biological sciences (2293 publications), chemical engineering (1217 publications) and social sciences (1142 publications), engineering (1128 publications) and materials science (662 publications).

Table 4: Most productive subject areas in toxicology research during 2008-2017

S. no.	Subject area	TP	Publication share (%)
1	Pharmacology, Toxicology and Pharmaceutics	13522	46.03
2	Medicine	10333	35.18
3	Environmental Science	7293	24.83
4	Biochemistry, Genetics and Molecular Biology	5015	17.07
5	Chemistry	3008	10.24

6	Agricultural and Biological Sciences	2293	7.81
7	Chemical Engineering	1217	4.14
8	Social Sciences	1142	3.89
9	Engineering	1128	3.84
10	Materials Science	662	2.25

Most productive affiliations

The research performance of top 15 most productive global affiliations in toxicology research during 2008-2017 is given in table 5. These 15 affiliations account for 12.94% (3801 publications) of total publication output in toxicology research during 2008-2017 with an average of 253 publications per institute. The highest number of papers were published by the United States Environmental Protection Agency (620 publications) followed by National Institute of Environmental Health Sciences (338 publications), Chinese Academy of Sciences (323 publications), Food and Drug Administration (320 publications) and Pfizer Inc. (264 Publications). National Institute of Public Health and the Environment registered the highest average citation per publication with 41.54 citations per paper followed by National Institutes of Health, Bethesda (36.26 citation per publication), United States Environmental Protection Agency (34.28 citation per publication), The University of North Carolina at Chapel Hill (33.59 citation per publication) and Karolinska Institutet (33.44 citation per publication). The average citation per publication of these 15 affiliations was 28.02. The United States Environmental Protection Agency registered the highest h-index (h=34), followed by National Institute of Environmental Health Sciences (h=30), Chinese Academy of Sciences (h=46) and The University of North Carolina, Chapel Hill and Food and Drug Administration (h=45 each). The average h-index of these 15 affiliations was 42.67.

Table 5: Research profile of most productive affiliations in toxicology research during 2008-2017

S. no.	Name of the affiliation	TP	TC	ACPP	Cited	% Cited	h-index
1	United States Environmental	620	21255	34.28	566	91.29	75

	Protection Agency						
2	National Institute of Environmental Health Sciences	338	10816	32.00	308	91.12	49
3	Chinese Academy of Sciences	323	8505	26.33	298	92.26	46
4	Food and Drug Administration	320	6587	20.58	276	86.25	45
5	Pfizer Inc.	264	5796	21.95	231	87.50	42
6	National Institutes of Health, Bethesda	262	9499	36.26	239	91.22	44
7	The University of North Carolina, Chapel Hill	197	6617	33.59	182	92.39	45
8	University of California, Davis	188	5538	29.46	169	89.89	34
9	Michigan State University	188	3930	20.90	175	93.09	36
10	Inserm	187	4439	23.74	159	85.03	38
11	Karolinska Institutet	187	6253	33.44	175	93.58	44
12	National Toxicology Program	186	4492	24.15	171	91.94	36
13	National Institute of Public Health and the Environment	184	7643	41.54	165	89.67	43
14	CNRS Centre National de la Recherche Scientifique	180	4878	27.10	160	88.89	38
15	Universidade de Sao Paulo – USP	177	2655	15.00	155	87.57	25

Most productive authors

The list of the top 15 most productive authors in toxicology research during 2008-2017 is given in table 6. These 15 productive authors have together contributed a total of 1137 papers to global toxicology research output with an average of 75.8 publications per author. The most active author in toxicology research during 2008-2017 was Api, A.M with 170 publications, 804 citations and h-index of 11. Five authors have published a higher number of papers than the group average of 75.8. These are Api A.M. (170 publications), Letizia C.S. (156 publications), Hartung T. (115 publications), Scognamiglio J (88 publications) and McGinty D (77 publications). Hoeng, J. registered the highest h-index (h=53) followed by Hartung T. (h=38), and

Andersen M.E. (h=26). These 15 productive authors have received a total of 17136 citations with an average citation per publication of 17.34.

Table 6: Most productive authors in toxicology research during 2008-2017

S. no.	Author name	TP	Current affiliation	TC	ACPP	h-index
1	Api, A.M.	170	Research Institute for Fragrance Materials, Inc., Englewood Cliffs, United States	804	4.73	11
2	Letizia, C.S.	156	Research Institute for Fragrance Materials, Inc., Englewood Cliffs, United States	328	2.10	8
3	Hartung, T.	115	Johns Hopkins University, Baltimore, United States	3936	34.23	38
4	Scognamiglio, J.	88	Research Institute for Fragrance Materials, Inc., Englewood Cliffs, United States	181	2.06	7
5	McGinty, D.	77	Research Institute for Fragrance Materials, Inc., Englewood Cliffs, United States	149	1.94	6
6	Klaassen, C.D.	59	University of Kansas Medical Center, Kansas City, United States	2408	40.81	24
7	Maurer, H.H.	59	Universitätsklinikum des Saarlandes Medizinische Fakultät der Universität des Saarlandes, Homburg, Germany	1730	29.32	26
8	Hoeng, J.	58	Philip Morris Products S.A., Neuchatel, Switzerland	1168	20.14	53
9	Madea, B.	57	Universität Bonn, Bonn, Germany	619	10.86	14
10	Andersen, M.E.	56	ScitoVation, LLC, Research Triangle Park, United States	2344	41.86	28

11	Peitsch, M.C.	54	Philip Morris Products S.A., Neuchatel, Switzerland	1082	20.04	19
12	Jones, L.	52	Research Institute for Fragrance Materials, Inc., Englewood Cliffs, United States	135	2.60	6
13	Piersma, A.H.	47	Utrecht University, Utrecht, Netherlands	1038	22.09	20
14	Musshoff, F.	45	Forensisch Toxikologisches Centrum (FTC) München, Munich, Germany	524	11.64	13
15	Drummer, O.H.	44	Monash University, Melbourne, Australia	690	15.68	16

Most productive journals

Top 15 most productive journals in toxicology research during 2008-2017 together contributed 7406 papers to total global publication output with a publication share of 33.27. The highest number of papers were published in *Toxicological Sciences* (2272) followed by *Forensic Science International* (716) and *Environmental Toxicology and Chemistry* (498). Among these most productive journals, *Toxicological Sciences* registered the highest average citation per publication of 29.51, followed by *Environmental Toxicology and Chemistry* (22.71) and *Chemosphere* (21.49). *Toxicological Sciences* received the highest h-index (h=102) followed by *Forensic Science International* (h=48) *and Environmental Toxicology and Chemistry* (h=45).

Table 7: Most productive journals in toxicology during 2008-2017

S. no.	Journal name	TP	TC	ACPP	Cited	% Cited	h-index
1	*Toxicological Sciences*	2272	67036	29.51	2217	97.58	102
2	*Forensic Science International*	716	12570	17.56	685	95.67	48
3	*Environmental Toxicology*	498	1131	22.71	456	91.57	45

	And Chemistry		1				
4	*Journal Of Medical Toxicology*	480	6537	13.62	417	86.88	35
5	*Indian Journal Of Forensic Medicine And Toxicology*	460	117	0.25	78	16.96	4
6	*Food And Chemical Toxicology*	377	4841	12.84	306	81.17	32
7	*Basic And Clinical Pharmacology And Toxicology*	348	5416	15.56	320	91.95	35
8	*Journal Of Toxicological Sciences*	341	2102	6.16	309	90.62	20
9	*Forensic Toxicology*	308	4292	13.94	288	93.51	31
10	*Regulatory Toxicology And Pharmacology*	296	5533	18.69	276	93.24	34
11	*Chemosphere*	290	6231	21.49	286	98.62	39
12	*Toxicologic Pathology*	283	3377	11.93	236	83.39	31
13	*Journal Of Analytical Toxicology*	274	3729	13.61	252	91.97	29
14	*International Journal Of Toxicology*	236	1987	8.42	175	74.15	20
15	*Journal Of Forensic Sciences*	227	2481	10.93	216	95.15	25

Most cited papers

Most cited papers in toxicology research for the period of 2008-2017 are shown in table 8. These 15 most cited papers were published in 10 journals including 2 papers each in *Chemical Society Reviews* and *Environmental Toxicology and Chemistry*, 1 paper each in *Chemical Research in Toxicology*, *Endocrine Reviews, Human Reproduction Update*, *International Journal of Nanomedicine*, *Journal of Nanoparticle Research*, *Nano Letters, Nature, Nature Toxicology, Science* and *small,*

respectively. Of these 15 papers, nine were published as review papers, 5 as articles and one as a book.

Table 8: Most cited papers in toxicology research during 2008-2017

S. no.	Title	Authors	Year	Journal title	TC	Type
1	Global Sensitivity Analysis. The Primer	Saltelli A., Ratto M., Andres T., Campolongo F., Cariboni J., Gatelli D., Saisana M., Tarantola S.	2008	Global Sensitivity Analysis. The Primer	2588	Book
2	Cytotoxicity of nanopartides	Lewinski N., Colvin V., Drezek R.	2008	Small	1812	Review
3	3D bioprinting of tissues and organs	Murphy S.V., Atala A.	2014	Nature Toxicology	1650	Review
4	Nanomaterials in the environment: Behavior, fate, bioavailability, and effects	Klaine S.J., Alvarez P.J.J., Batley G.E., Fernandes T.F., Handy R.D., Lyon D.Y., Mahendra S., McLaughlin M.J., Lead J.R.	2008	Environmental Toxicology and Chemistry	1624	Review
5	Drug delivery and nanoparticles: Applications and hazards	De Jong W.H., Borm P.J.A.	2008	International Journal of Nanomedicine	1539	Review
6	Graphene in mice: Ultrahigh in vivo tumor uptake and efficient photothermal therapy	Yang K., Zhang S., Zhang G., Sun X., Lee S.-T., Liu Z.	2010	Nano Letters	1439	Article
7	Reconstituting organ-level lung functions on a chip	Huh D., Matthews B.D., Mammoto A., Montoya-Zavala M.,	2010	Science	1342	Article

		Yuan Hsin H., Ingber D.E.				
8	Hormones and endocrine-disrupting chemicals: Low-dose effects and nonmonotonic dose responses	Vandenberg L.N., Colborn T., Hayes T.B., Heindel J.J., Jacobs D.R et al.	2012	Endocrine Reviews	1245	Review
9	Clinical efficacy of a RAF inhibitor needs broad target blockade in BRAF-mutant melanoma	Bollag G., Hirth P., Tsai J., Zhang J., Ibrahim P.N. et al.	2010	Nature	1127	Article
10	Upconversion nanophosphors for small-animal imaging	Zhou J., Liu Z., Li F.	2012	Chemical Society Reviews	1091	Review
11	Adverse outcome pathways: A conceptual framework to support ecotoxicology research and risk assessment	Ankley G.T., Bennett R.S., Erickson R.J., Hoff D.J., Hornung M.W et al.	2010	Environmental Toxicology and Chemistry	978	Review
12	World Health Organization reference values for human semen characteristics	Cooper T.G., Noonan E., von Eckardstein S., Auger J., Baker H.G. et al	2009	Human Reproduction Update	945	Article
13	Characterization of size, surface charge, and agglomeration state of nanoparticle dispersions for toxicological studies	Jiang J., OberdÃ¶rster G., Biswas P.	2009	Journal of Nanoparticle Research	898	Article
14	Nano-graphene in biomedicine: Theranostic applications	Yang K., Feng L., Shi X., Liu Z.	2013	Chemical Society Reviews	865	Review

15	Cytochrome P450 and chemical toxicology	Guengerich F.P.	2008	Chemical Research in Toxicology	854	Review

Summary and discussion

Scientometric analysis of toxicology research based on SCOPUS records shows a remarkable growth in global publications output during 2008-2017, increasing from 2231 to 3620. During 2008-2017, the United States produced the highest number of papers in toxicology research, accounting for about 35.84 per cent of the global publication output followed by China (7.94%) and United Kingdom (7.92%). It is a huge lead, perhaps, and the toxicology research output of the USA still outranks China and the other countries in terms of quality of scientific papers. Among the subjects, pharmacology, toxicology and pharmaceutics contributed the largest share of 46.03% followed by Medicine (35.18%) and Environmental Science (24.83%). Api A.M. published the highest number of papers (170) followed by Letizia C.S. (156) and Hartung T. (115). The 15 most productive authors together contributed a total of 1137 papers with an average citation per publication of 17.34. Among affiliations, the highest number of papers were published by the United States Environmental Protection Agency (620 publications) followed by National Institute of Environmental Health Sciences (338 publications) and Chinese Academy of Sciences (323 publications). Top 15 global leading organisations contributed 12.94% share to global toxicology research during 2008-2017. Most preferred journals by authors were *Toxicological Sciences*, *Forensic Science International* and Environmental Toxicology and Chemistry. Top 15 most productive journals contributed 25.21% share of the total global publication in toxicology research during 2008-2017.

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