A bibliometric Profile of World Nuclear Weapons Research Outputfrom 2010 to 2019: A Scientometric Analysis based on WoS Database

K.P.S. Sengar
Head, KRC, CSIR-IMTECH, Chandigarh
E-mail: kps@imtech.res.in

Rajesh Kumar Lohiya
Head, KRC, CSIR-NEERI, Nagpur
Email: rk_lohiya@neeri.res.in

Abstract

This study attempts to highlight the growth and development of world literature on Nuclear Weapons in terms of publication output from Science Citation Index- Expanded (Web of Science) during the year 2010-2019. During this period, a total of 3824 papers were published by researchers worldwide in the field of Nuclear Weapons. The average number of publications published per year was 382. 426 articles were published in the year 2017, which is the highest number of paper published during the study period. There were 100 countries involved in the research in this field. USA is the top producing country with 1681 (43.959% global share) followed by Japan with 478 (12.5% global share). United States Department of Defense, USA, has the highest number of publications with 307 (8.02% global share) followed by the National Institute of Health, USA with 287 (7.50% share) papers.9905 authors have contributed to the 3824 papers during 2010-2019. H.M. Kristensen is the most prolific author, who has published 58 (1.517% share) papers during the study period. The publication in the form of journal articles was about 73%. English was the utmost preferred language used by researchers for scholarly communication. About 98.143% of publications were in the English language. The analysis of the subject areas of research papers indicates that most of the core journal deals “International Relations”, “Radiology Nuclear Medicine MedicalImaging”. Top ten funding agencies retrieved in the study show that funding is mostly government-funded in the USA, Japan, and China. The study shows that most frequently used keywords were Atomic Bomb Survivors, Nuclear Weapons, Plutonium, CS-137, Radionuclides, etc.

Keywords: *Nuclear Weapons; Atomic Weapons; Atomic Bomb; Neutron Weapons; Scientometric*

1. Introduction

According to Britannica,“nuclear weapons device designed to release energy explosively as a result of nuclear fission, nuclear fusion, or a combination of the two processes. Fission weapons are commonly referred to as atomic bombs. Fusion weapons are also referred to as thermonuclear bombs or, more commonly, hydrogen bombs; they are usually defined as nuclear weapons in which at least a portion of the energy is released by nuclear fusion”.“Nuclear weapons technology was developed during the 1930s and 1940s. The first nuclear weapons were detonated over Hiroshima and Nagasaki in August 1945. Since then, controlling the proliferation of nuclear weapons has been an important issue in international relations and the two detonations in Japan remained the only ever usage in warfare” [1] Based on the information is given in “SIPRI (Stockholm International Peace Research Institute) year book 2019 relating to the availability of a total list of nuclear weapons globally, 13865 nuclear weapons, 3750 are deployed with operational forces and around 2000 of these are placed in high operational alert status. More than 90% of the world's nuclear weapons were owned by Russia and the United States”2.Scientometric is a widely accepted method for the purpose of observation and evaluation. Despite its limitations, this method provides a position regarding the status of a country's national innovation system. It is necessary to monitor and evaluate various aspects of the scientific enterprise as it is an integral part of science policy. The scientometric approach measures the availability of research with necessary and impact.

2. Literature Review

Research into specificscientometric and citation analysis study has a long history. Many scientometric studies have been conducted on different subject domains. For instance, Leeuwen&Tijssen3conducted a quantitative survey of Dutch Nuclear Energy research entire publications Production, observing at its relative contribution to global production in SCI journals. Rekha, Kedamani, Surwase& Kumar [4] analyzed 257 articles published by the researchers of the Nuclear Physics Division, Bhabha Atomic Research Centre, India, and it was shown that the average number of citations per year was 703.38.Venkatesan& Shanmugam5have examines the growth of research outcomes in terms of articles on nuclear power generation at the global level from 1980 to 2013. The study found that from the year 1999 to 2013, papers increased with an average of 134 records per year.Sudarsana& Babu6 based on scientometric

studies, reported the global nuclear fuel research over a time from 2000-2017. The total number of records is 7420 has been recorded form web of science. They analyzed publication productivity, prolific authors and their networks, prolific institute and citation pattern. For visualization, they used the "CiteSpace and VOSviewer" software. The 4166 publication published during 2011-2017, and that is 56%.The "Korean Atomic Energy Research Institute" is the main contributor, and the "USA, France, South Korea and Germany" is having significant development in this area. Busygina& Rykova [7] assessed scientometric visualization of the documentary array on Semipalatinsk nuclear test site, based onthe Web of Science databases. They find out the authors, organizations, countries, publications in the related field. They used CiteSpace software for the visualization of co-citation networks. The analyzed the effect of nuclear test and its effects on the environment in the site and related aspect also. Gupta & Dhawan8 assessed quantitative and qualitative contribution of global machine translation research during 2007-2016, on the bases of Scopus databases. They analyzed publication growth, citation patterns, international collaboration, countries, organisations, prolific authors and highly cited papers.Kademani, Kumar, Sagar, & Kumar [9] presented a quantitative analysis of nuclear science and technology research growth as well as development in India, on the basis of International Nuclear Information System (INIS) databases during 1970-2002. The total number of record during the period is 55313 has been recorded. The analysed publication growth, author's trends and colouration patterns and most prolific journals. Dhawan, Gupta, & Gupta10 has been reported 34641 article on mobile computing research globally in this paper and data taken from SCOPUS databases during 2007-16. They found that 9.35% growth rate annually and 3.39% citation per paper. They also analyses the productive countries, an International collaboration of publications, citation analysis, Author analysis and Source journals analysis.

3. Objectives

Following are the objectives of the study:

- To examine the pattern of annual growth of literature in the area of nuclear weapons,
- To find out citations received in each year,
- To find out the type of documents,
- Geographical distribution of output,
- Institutional distribution of research output,

- Highly productive journals in nuclear weapons areas,
- High prolific authors in this research area,
- Language-wise distribution of publications,
- Main subject fields used by nuclear weapons researchers,
- Funding agencies involved in nuclear weapons
- Explore the keywords in "Nuclear Weapons" research used by researchers

4. Methodology

The primary data was retrieved fromWeb of Science database. WoS database is one of the comprehensive citation database on almost all aspects of science covering thousands of journals. Keeping in view, the importance of the research topic on nuclear weapon in the present scenario, the following search strategy was used to retrieved records: Most relevant terms associated with nuclear weapons i.e. atomic bomb, hydrogen bomb, and neutron bomb are included with the following **search strategy*:TS= (atomic bomb or hydrogen bomb or neutron bomb or nuclear weapons) Timespan: 2010-2019. Index: SCI-Expanded, SSCI, CPCI-S, CPCI-SSH, CCR-Expanded, IC.*** There are a total of 3824 papers taken and analyzed according to the objectives of the study using bibliometric techniques.

Relative Growth Rate:

The relative growth rate is the increase in the number of publications. The growth rate of total papers has been calculated on the relative growth rate and doubling time model developed by Mahapatra (1985). The mean relative growth rate [R (1-2)] over a specified period of the interval can be calculated from the following equation.

$$Relative\ Growt\square\ Rate(RGR) = \frac{L2 - L1}{T2 - T1}$$

Here R = relative growth rate of articles/citations/pages over a specific period.

L1 (Loge) = Log of initial number of articles/citations/pages

L2 (Loge) = Log of final number of articles/citations/pages

Doubling Time:

Doubling time (Dt) is directly related to RGR. If the number of publications of subject doubles during a given period, then the difference between the logarithms of the numbers at the beginning and at the end of the period must be the logarithms of the number 2. If one uses natural logarithms, this difference has the value of 0.693. Thus, the corresponding doubling time for publications, citations and pages can be calculated by the following formula:

$$Doubling\ Time(Dt) = \frac{0.693}{R}$$

Here, Dt = The average doubling time of publications.

5. Data Analysis and Discussions

5.1 Annual Growth of Publications on Nuclear Weapons:

During 2010-2019 a total of 3824 papers were published on nuclear weapons by different nations. The highest number of the output of 426 papers in 2017. The average number of articles published per year on nuclear weapons is 382.4. The data collected from 2010-2019 shows that literature grows almost steady except during 2012, 2014-16, when it decreased from the previous year. Table 1 givesan annual growth rate in nuclear weapons research. The Relative Growth Rate [RGR] and Doubling Time [Dt(P)] of publications was calculated and presented in table 1. It can be observed from the table that the Relative Growth rate of Publication [RGR] increased from the rate -0.042 in 2011 to 0.016 rate in 2012 and again decreased in 2013. Table also shows that mean relative growth rate for the five years i.e. 2011 to 2015indicated a growth rate of 0.01 whereas the mean growth rate for the last 4 years(i.e. 2016-2019) reduced to -0.007. The corresponding Doubling Time gradually increases from -16.5 in 2011 to 43.21 in 2012 and again decreased in 2013. The mean Doubling Time for the first five years(i.e. 2011-2015) was 12.340 which was decreased to 6.280during the last four years (i.e. 2016-2019). Thus, as the growth rate of the publication decreased, the Doubling Time also reduced. It is shown that no definite pattern of the value of RGR of articles [R(p)] can be ascertained (refer table 1, fig. 1)

Table 1

Annual growth of publications

Year	Publications	Cumulative Publications	Log 1 (L1)	Log 2 (L2)	RGR (L2-L1)	Mean RGR	Dt (P)	Mean Dt (P)
2010	378	378	--	5.934	--		--	
2011	362	740	5.934	5.892	-0.042		-16.5	
2012	368	1108	5.892	5.908	0.016		43.31	
2013	347	1455	5.908	5.849	-0.059	0.01	-11.7	12.340
2014	353	1808	5.849	5.866	0.017		40.76	
2015	397	2205	5.866	5.984	0.118		5.873	
2016	404	2609	5.984	6.001	0.017		40.76	
2017	426	3035	6.001	6.054	0.053	-0.007	13.08	6.280
2018	403	3438	6.054	5.999	-0.055		-12.6	
2019	386	3824	5.999	5.956	-0.043		-16.1	
	3824		5.956			**0.0015**		**9.31**

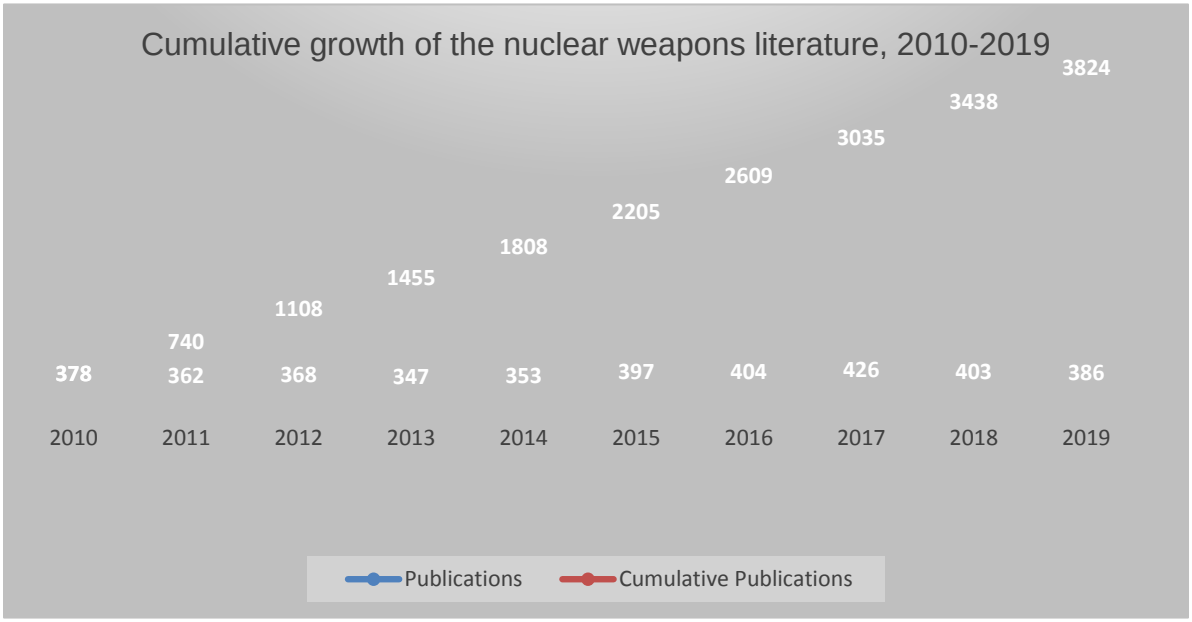

Figure 1. Cumulative growth of the nuclear weapons literature

5.2 Citations Analysis:

Citation has always been used as a reflection of quality and impact of scientific papers. Fig. 2 shows that highest citations was received from the year 2019. 38129 citations received of total articles during the study period. The average citation per article is 9.97. (**refer fig 2**)

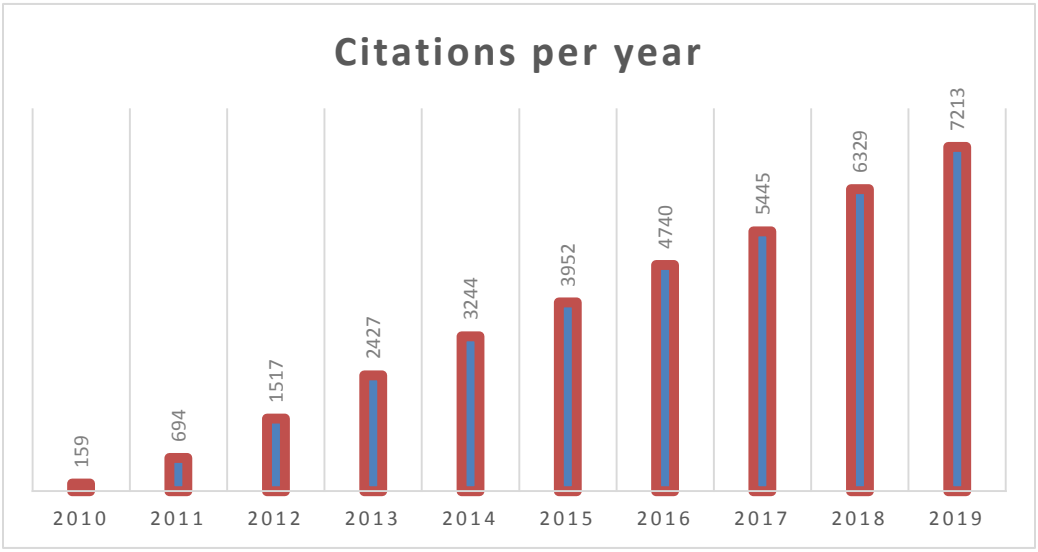

Figure 2. Citations per year

5.3 Document Types:

Nuclear Weapons researchers used a wide variety of documents where their research is published. Table 2 and Fig. 3 shows the type of distribution of documents on nuclear weapons. The number of publications in the form of journal articles is 2801 (73.25%). It is also found that 8.028% of total literature of covered in conference proceedings. Most of document type on nuclear weapons that are collected in the WoS is in the form of journal articles or conference proceedings, consulting 81.27% of the total research articles, demonstrating that nuclear weapons researches given importance to timelines and originality.

Table 2

Document type of publications

Document Types	Publications	% of 3824
Article	2801	73.25
Proceedings Paper	307	8.028
Review	288	7.531
Editorial Material	145	3.792
Book Review	135	3.53
Letter	68	1.778
Meeting Abstract	43	1.124
News Item	17	0.445
Correction	13	0.34
Biographical Item	4	0.105
Chronology	2	0.052
Bibliography	1	0.026
Total	**3824**	**100**

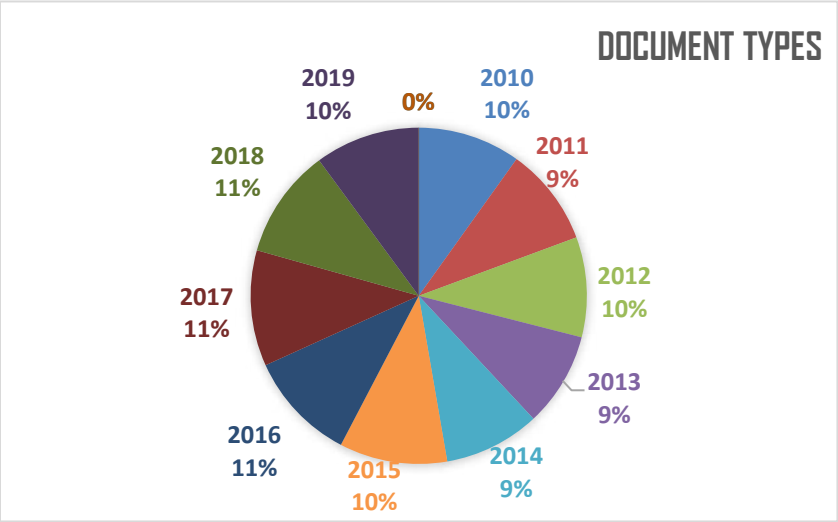

Figure3. Document type

5.4 Institution Distribution of Research Output:

During the study period in nuclear weapons research output, 3124 institutions contributed articles which include research, academic and universities, government institution and private organisations. Among the contributed institutions, top 10 institutions are provided in table 3. Among the top contributing institutions, highest number of papers was produced by United States Department of Defense, DOE, USA with 307 (8.02% global share) followed by National Institute of Health with 287 (7.50% share) papers, Radiation Effects Research Foundation Japan with 185 (4.83% share) etc. Further analysis of these institutes on the basis of their host countries shows that USA is at the top with 6 Institutes, followed by Japan with 3 institutes. Rest of the institutes belong to different countries. During the retrieving of data from WoS 219 records has not contained country information.

Table 3

Institution distribution of research output

S.No.	Institute	Publications	% of 3824	Rank
1	United States Department of Defense, DOE, USA	307	8.02	1

2	National Institute of Health, USA	287	7.50	2
3	Radiation Effects Research Foundation Japan	185	4.83	3
4	Helmholtz Association, Germany	157	4.10	4
5	University of California System, USA	119	3.11	5
6	Harvard University, USA	83	2.17	6
7	Hiroshima University, Japan	70	1.83	7
8	University of Texas System, USA	56	1.46	8
9	Nagasaki University, Japan	53	1.38	9
10	Stanford University, USA	53	1.38	9
11	University of London, U.K.	53	1.38	9
12	National Institute of Radiological Sciences, Japan	42	1.09	10
13	Other Countries	2359	61.68	--
	Total	**3824**	**100**	

5.5 Geographical Distribution of Output:

A total of 100 countries produced literature on nuclear weapons. Table 4 list of top ten countries on the basis of their publication output. Of these, USA contributed maximum papers of 1681 (43.959% global share). USA was followed by Japan with 478 (12.5% global share) articles, England with 336(8.787% global share) articles. India stands at 15th position with only 50 (1.308% global share) papers that were covered in WoS during the study period of 2010-2019. This is a matter of concern that India is not publishing large number of papers in nuclear weapons.

Table 4

Geographical distribution of output

Countries/Regions	Publications (% of	Citations

	3824)	
USA	1681 (43.959%)	20333
Japan	478 (12.5%)	5929
England	336 (8.787%)	5717
Germany	228 (5.962%)	3304
Peoples R China	203 (5.309%)	2168
France	152 (3.975%)	4377
Australia	147 (3.844%)	1933
Russia	146 (3.818%)	1445
South Korea	116 (3.033%)	857
Canada	114 (2.981%)	2013

5.6 High Prolific Authors:

A total number of 9905 authors have been contributed to the 3824 papers during 2010-2019. Table 5 provide data of top ten highly productive authors, affiliation of the author, citations and h-index. These ten authors together have contributed 393 (10.27% share) papers. H.M. Kristensen from is the most prolific author, who has published 58 (1.517% share) papers during 2010-2019 and these have received 279 citations, with an average of 4.81 citations per paper followed by R.S. Norris with 49 (1.229% share) papers and these have received 263 citations, with an average of 5.6 citations per Paper. It is clear that both the top authors belong to the same organisation i.e. Federation of American Scientists, Nuclear Information Project, Washington, USA. The h-index value varies from 8 to 16 during the study period.

Table 5

High Prolific Authors

Authors	Affiliation	No of paper (% of	Citation received	ACPP	h-Inde

		global share)			**x**
Kristensen HM	Federation of American Scientists Nuclear Information Project, Washington, DC, USA	58 (1.517)	279	4.81	9
Norris RS	Federation of American Scientists Nuclear Information Project, Washington, DC, USA	47(1.229)	263	5.6	9
Ozasa K	Hirosoft International, Eureka, California, USA	46(1.203)	1466	31.43	16
Little MP	National Cancer Institute, NIH, USA	42(1.098)	1094	26.05	16
Cullings HM	*Radiation Effects* Research *Foundation* Hiroshima, Japan	38(0.994)	543	14.29	10
Ohishi W	*Radiation Effects* Research *Foundation*Hiroshima, Japan	35(0.915)	235	6.71	8
Preston DJ	Hirosoft International, Eureka, California, USA	34(0.889)	801	23.56	15
Grant EJ	*Radiation Effects* Research *Foundation* Hiroshima, Japan	32(0.837)	1141	35.56	15
Sakata R	*Radiation Effects* Research *Foundation* Hiroshima, Japan	31(0.811)	1079	34.81	14
Laurier D	Institute for Radiological Protection and Nuclear Safety, France	30(0.785)	878	29.27	14

5.7 Highly Productive Journals:

The total number of journals used by the researchers was 1315 which produced 3517 articles. Table 6 depicts the top ten highly productive journals in the field of nuclear weapon. The leading journals are Bulletin of The Atomic Scientists (236, 6.172% share), Radiation Research (147, 3.844% share), Health Physics (114, 2.981% share) and so on. Table 6 also includes the country of origin of the journal and impact factor of the year 2018. It is clear that out of top 10 journals 04 journals published from UK and 03 Journals from USA. Single journal from Netherlands, Germany and South Korea respectively. It again indicates that USA and UK is giving more attention to nuclear weapons research than rest of the other countries.

Table 6

\Highly productive journals

Name of Journal	Country of Origin	Publications (% of 1315)	Impact Factor (2018)
Bulletin of The Atomic Scientists	UK	236 (6.172%)	1.368
Radiation Research	USA	147 (3.844%)	2.779
Health Physics	USA	114 (2.981%)	0.993
Journal of Environmental Radioactivity	Netherlands	85 (2.223%)	2.179
Radiation and Environmental Biophysics	Germany	67 (1.752%)	1.267
International Affairs	UK	50 (1.308%)	3.748
Korean Journal of Defense Analysis	South Korea	49	0.200

		(1.281%)	
Survival	UK	47	1.264
		(1.229%)	
Journal of Radiological Protection	UK	44	1.327
		(1.151%)	
International Security	USA	43	4.500
		(1.124%)	

5.8 Languages-wise Distribution of Publications

English was the leading language of publications on nuclear weapons. Table 7 shows that English language articles found 98.143% of the total publications on nuclear weapons. There are only 2% non-English language articles. It is clear that English is the formal language for most international conferences as well as magazines. Also the coverage of WoS is mostly English language publication sources.

Table 7

Languages-wise distribution of publications

Languages	Publications	% of 3824
English	3753	98.143
German	19	0.497
French	10	0.262
Russian	10	0.262
Chinese	8	0.209

Turkish	4	0.105
Czech	3	0.078
Japanese	3	0.078
Norwegian	3	0.078
Portuguese	3	0.078
Slovak	2	0.052
Croatian	1	0.026
Hungarian	1	0.026
Italian	1	0.026
Korean	1	0.026
Polish	1	0.026
Slovenian	1	0.026
	3824	**100**

5.9 Main Subject Research Areas:

Total 134 subject research areas were retrieved from WoS database. Nuclear Weapons literature is quite expanded in their subject coverage as indicated in the table 8. Table shows the top ten research areas were most of the research articles of nuclear weapons have been published by the researchers. International relations 874 (22.856% share) articles, Radiology Nuclear Medicine Medical Imaging 632 (16.527% share), Environmental Sciences Ecology 560 (14.644% share) articles holds 1st, 2nd and 3rd ranks in the research publications respectively.

Table 8
Main Subject Areas

Research Areas	Publications	% of 3824
International Relations	874	22.856

Radiology Nuclear Medicine Medical Imaging	632	16.527
Environmental Sciences Ecology	560	14.644
Nuclear Science Technology	477	12.474
Government Law	377	9.859
Public Environmental Occupational Health	333	8.708
Life Sciences Biomedicine Other Topics	290	7.584
Engineering	241	6.302
Social Issues	241	6.302
Biophysics	221	5.779

5.10 Funding Agencies Involved in Nuclear Weapons:

A brief analysis of the top 10 funding agencies out of 1652 agencies involved in nuclear weapons research worldwide shows that they are all government funded. This shows that their country is supporting the research activities in this area. Highest number of papers was published as a result of research funded by National Institute of Health, USA with 497 (12.99% share) papers followed by United States Department of Energy, USA. Table 9 shows top 10 funding agencies involved in nuclear weapons research around the globe.

Table 9
Funding Agencies Involved in Nuclear Weapons

S.No.	Funding Agencies	Publications	% of 3824	Rank
1	National Institutes of Health, USA	497	12.99	1
2	United States Department of Energy, USA	324	8.47	2
3	United States Department of Health Human Services, USA	243	6.35	3
4	Ministry Of Health Labour And Welfare Japan	183	4.79	4

5	Ministry Of Education Culture Sports Science And Technology, Japan	102	2.66	5
6	National Natural Science Foundation of China	97	2.54	6
7	Radiation Effects Research Foundation, Japan	77	2.01	7
8	European Union, Belgium	57	1.49	8
9	Japan Society for the Promotion of Science, Japan	56	1.46	9
10	National Aeronautics Space Administration, USA	39	1.01	10
11	Other Funding Agencies	2188	57.21	--
	Total	**3824**	**100**	

5.11 Visualization of the Keyword Analysis

Figure 10 indicates the analysis of the keywords using the density panel at **VOSViewer** of nuclear weapons-related papers during 2010-2019 in WoS and stated that a total of 12482(authors keywords and keywords plus) keywords in used during the entire period. It can be seen in figure 10, the 05 most frequently used keywords. In this figure, the font size and background colourred with background yellow represent the highest numbers of keywords occurrence. The first and most frequent keyword was " atomic bomb survivors" with 811 existence followed by the word " nuclear weapons "327-time occurrences, “Plutonium” 116 times, “CS-137”104 times and "radionuclides" 78 times occurrence and got second, third, fourth and fifth positions, respectively.

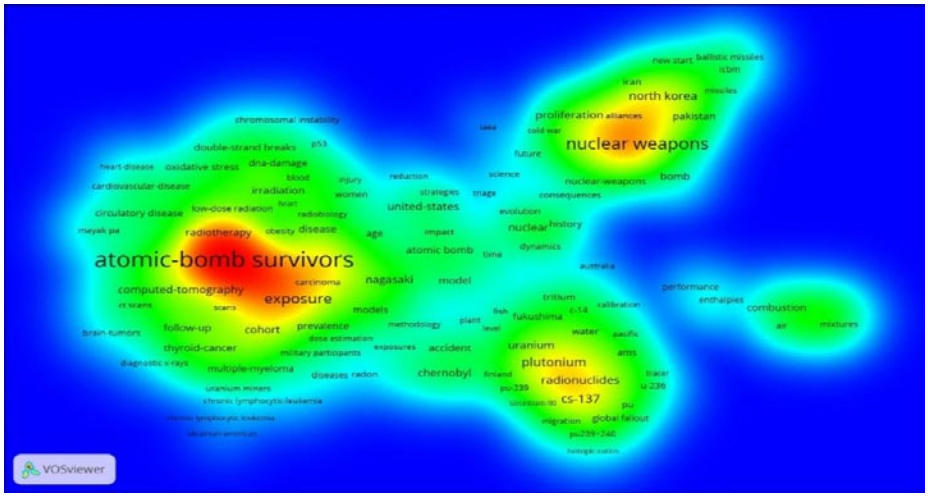

Figure 4. Visualization of the Keyword Analysis

6. Findings and Conclusion

This study provides a quantitative sketch of nuclear weapons research covering the study period from 2010 to 2019. The publications and citations were retrieved from WoS database. It is found that research on nuclear weapons areas conducted across 100 countries during the study period. The study found that literature on nuclear weapons grows almost steady except the year 2012, 2014-2016. It is revealed that no definite pattern of the value of RGR of article [Dt(p)] can be ascertained. The global publication share on top 10 countries ranged between 2.981% to 43.959% end together they accounted for 95% share during the study period. U.S.A ranks top with 43.959% global publication share followed by Japan with 12.5% share It is found that journal articles is a single form of publication that widespread and contributes 73% in the whole literature of nuclear weapons. It is found that most of the articles on nuclear weapons are published in English language only. In fact 98% articles of the total literature are in English language. In terms of highly productive author, H.M Kristensen is the most prolific author, who has published 58 (1.517%share) papers during 2010-2019. It is found that 3517 articles were published in 1315 peer reviewed journals. The study also indicates that USA has the largest number of institutes involved in nuclear weapons research. The top ten funding agencies show that most government funding is in the United States, Japan, and China. The study shows that most frequently used keywords were atomic bomb survivors, nuclear weapons, plutonium, CS-137, radionuclides, etc.

The aim of the study is to help nuclear weapons researchers and those who are framing the policies. On the basis of the study the government of various countries can take the facts into account and frame a suitable policy.

References

Busygina T V and Rykova (V V). Scientometricvisulisation of the documentary array on Semipalatinsk Nuclear Test site. D*ESIDOC Journal of Library & Information Technology*. 39,4; 2019; 152-161.

Dhawan SM, Gupta B M and Gupta R. (2017). Mobile computing: a scientrometric assessment of global publications output. *Annals of Library and Information Studies*. 64,3; 2017; 172-180.

Gupta B M and Dhawan S M Machine translation search: a scientometric assessment of global publications output during 2007-16. *DESIDOC Journal of Library & Information Technology*.39,1; 2019; 31-38. https://www.nti.org/analysis/articles/us-nuclear-weapons-budget-overview

Kademani BS, Kumar V, Sagar A and Kumar A. Scientometric dimensions of nuclear science and technology research in India: A study based on INIS (1970-2002) database. *Malaysian Journal of Library & Information Science*.11,1; 2006; 23-48.

Mahapatra M (1985). On the validity of the theory of exponential growth of scientific literature. 15th IASLIC Conference, 1985. *IASLIC*, Calcutta.

ROSER (M) and NAGDY(M). Nuclear Weapons. Published online at OurWorldInData.org. (Retrieved from: 'https://ourworldindata.org/nuclear-weapons') (Access on May 20.,2020)

Sudarsana D and Babu M S . Global nuclear fuel research during 2000 to 2017: A scientrometric analysis. *Annals of Library and Information Studies*. 66,3; 2017; 85-93.

Upadhye R P et. al. Scientrometricdimentions of the Nuclear Physics Division at Bhaba Atomic Research Centre. *SRELS Journal of Information Management*.47, 4; 2010.

Van leeuwen T N and Tijssen R J W. Assessing multidisciplinary areas of science and technology: A synthetic bibliometric study of Dutch nuclear energy research. Scientometrics.26, ;1993;115–133. Zttps://doi.org/10.1007/BF02016796(Access on May 20.,2020)

Venkatesan M and thanuskodi S A Scientrometric analysis of nuclear power generation research: a study. *International Journal of Library and Information Studies*. 4,3; 2018; 65-75.