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Research Trends in Radioisotopes: A Scientometric Analysis (1993-2012)

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ABSTRACT

This paper attempts to highlight the publication status and growth of radioisotope research across the world and make quantitative and qualitative assessment by way of analysing various features of research output based on Web of Science database during the period 1993-2012. A total of 31488 publications were published on radioisotopes, which received 482549 citations. The average number of publications per year was 1574.40 and the average number of citations per publication was 15.32. The publications peaked in the year 2012 with 2036 publications and the highest number of citations (33316) was in 1999. The parameters studied include: year-wise growth of publications and citations, continent-wise distribution of publications and citations, country-wise distribution of publications, distribution of publications according to impact factor range, international collaboration, domain-wise distribution of publications and citations, highly productive institutes, highly cited publications and highly preferred journals for publications by scientists.

Keywords: Radioisotopes, scientometrics, publication productivity, R&D trend, research quality, publication efficiency index, specialisation index

1. INTRODUCTION

Radioisotopes or radionuclides are radioactive forms of elements and are usually produced in research reactors and accelerators. They have wide ranging applications in healthcare, industry, food & agriculture and environmental monitoring. Following over five decades of vast experience accumulated, radioisotope technology has developed to a high degree of sophistication and it is estimated that about 200 radioisotopes are in regular use.

Scientometrics is a discipline which analyses scientific publications and citations appended to the papers to gain an understanding of the structure of science, growth of science at global level, performance of a country in a particular domain, performance of institutions, departments/divisions and scientific eminence of an individual scientist. It also helps in knowing the information seeking behaviour of scientists and engineers by way of identifying where they publish and what they cite. Many scientometric studies on nuclear science and technology have been carried out.

2. LITERATURE REVIEW

Kademani[1], *et al*. have analysed quantitatively the growth and development of nuclear science and technology research in India in terms of publication output as reflected in International Nuclear Information System (INIS) (1970-2002) database. Kademani[2], *et al.*, have done detailed quantitative analysis of Indian contributions on thorium in terms of publications output as per INIS database during 1970-2004. A total of 2399 papers were published by the Indian scientists in the field of thorium. Kademani[3], *et al*., carried out a study on world literature on thorium in terms of publication output as per Science Citation Index (1982-2004). A total of 3987 papers were published. The study also identified the highly productive institutions, extent of international collaboration, most prolific authors in the field, etc. Kademani[4], *et al*., have analysed 65592 publications on zirconium in nuclear science and technology using the INIS database as a tool. The study focused on the broad features of zirconium literature such as year-wise distribution of publications, country-wise distribution of publications, country-wise activity index, domain-wise distribution of publications and highly productive institutions. Sagar[5], *et al.*, have presented the growth of literature on cobalt-60 research in nuclear science and technology by way of analysing various characteristic of research output such as the growth of publications, geographical

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distribution of publications, publication productivity-wise distribution of publications. There is a lot of research being carried out all over the world in the field of radioisotopes and their applications in various fields such as healthcare, industry, food and agriculture, and environmental monitoring. It was felt important to carry out a study as there are not many scientometric studies conducted in the field of radioisotopes.

3. OBJECTIVES

The objective of the study is to perform a scientometric analysis of all radioisotope research publications in the world. The parameters studied include growth of publications and citations, continent-wise distribution of publications and citations, country-wise distribution of publications, publication efficiency index, international collaborative index, domain-wise distribution of publications and citations, specialisation index, highly productive institutes, quality of research, identification of highly cited publications and highly preferred journals.

4. MATERIALS AND METHODS

The Web of Science database was used for retrieving data on radioisotopes during 1993-2012, using search terms namely 'radioisotope* or radionuclide*' in 'topic' field. A total of 31488 publications and 482549 citations received to these publications were transferred to spread sheet application. The bibliographic fields were analysed by normal count procedure for continents, countries, domains, authorships, and journals. Full credit was given to each continent, country regardless of whether it appears first or last in the author byline.

5. RESULTS AND DISCUSSIONS

5.1 Year-wise Growth of Publications and Citations

A total of 31488 publications were published on radioisotopes during 1993-2012 and these publications received 482549 citations. Year-wise distribution of publications and citations is given in Fig. 1. The highest number of publications 2036 (6.47 %) was published in 2012. The highest number of citations 33316 (6.90 %) was received in 1999. The highest average citations per publication was 24.77 in 1993. There were 4421 (14.04 %) publications with no citations during the period under study. Overall collaboration coefficient was very high (0.91) as 28729 (91.21 %) publications of the total documents were multi-authored and the highest collaboration rate (0.94) was in 2010 and 2011. An exponential growth of publications was observed in this study.

5.2 Continent-wise Share of Publications/ Citations

Publications from Australia/Oceania received the highest average number of citations (24.36) per publication followed by North America (22.61), Europe (16.21), South America (10.05) and Asia (8.66) and Africa (7.64). Distribution of publications and citations of top five countries in each continent is given in Table 1.

5.3 Highly Productive Countries in Radioisotope Research

In all, there were 134 countries involved in research in radioisotope field and which published at least one publication. The USA topped the list with highest share (29.31 %) of publications. Germany ranked second with 8.16 % share of publications followed by England with 7.44 % share of publications, Japan with 6.97 % share of publications, France with 6.38 % share of publications, Italy with 4.75 % share of publications, Russia with 4.73 % share of publications, Canada with 3.3 % share of publications, Spain with 3.17 % share of publications, Sweden with 3.07 % share of publications, Netherlands with 3.03 % share of publications, Switzerland with 2.72 % share of publications and India with 2.63 % share of publications (Table 2).

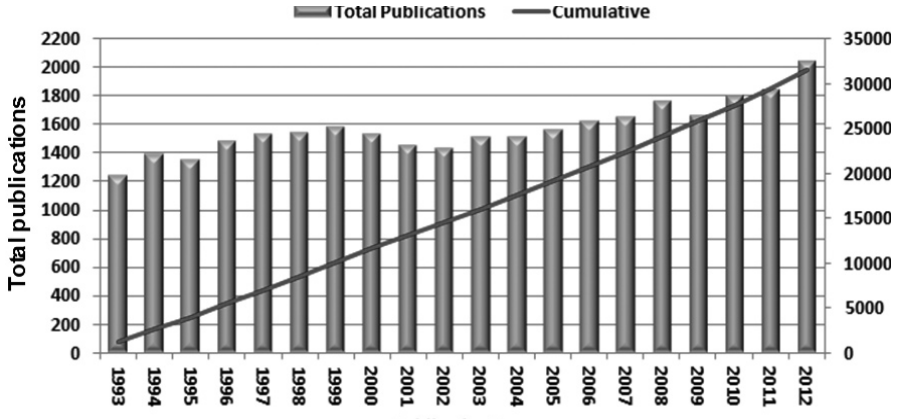

Figure 1. Year-wise distribution of publications.

Table 1. Distribution of publications and citations of top five countries in each continent

Continents	Country	Rank	Total publications (%)	Total citations (%)	Average citations/ publication (ACP)	Publication efficiency index
Africa	Egypt	1	289 (0.92 %)	2124 (0.44 %)	7.3	0.48
	South Africa	2	152 (0.48 %)	1564 (0.32 %)	10.3	0.67
	Nigeria	3	91 (0.29 %)	397 (0.08 %)	4.4	0.28
	Morocco	4	49 (0.16 %)	343 (0.07 %)	7.0	0.46
	Algeria	5	24 (0.07 %)	277 (0.06 %)	11.5	0.75
Asia	Japan	1	2194 (6.97 %)	25433 (5.27 %)	11.6	0.76
	Russia	2	1490 (4.73 %)	7758 (1.61 %)	5.2	0.34
	India	3	828 (2.63 %)	5960 (1.23 %)	7.2	0.47
	Peoples R China	4	795 (2.52 %)	7109 (1.47 %)	8.9	0.58
	Turkey	5	665 (2.11 %)	4514 (0.93 %)	6.8	0.44
Australia/ Oceania	Australia	1	652 (2.07 %)	13999 (2.90 %)	21.5	1.40
	New Zealand	2	103 (0.33 %)	4405 (0.91 %)	42.8	2.79
	Marshall Island	3	1 (0.003 %)	10 (0.002 %)	10.0	0.65
Europe	Germany	1	2568 (8.15 %)	43202 (8.95 %)	16.8	1.10
	England	2	2344 (7.44 %)	44261 (9.17 %)	18.9	1.23
	France	3	2009 (6.38 %)	32511 (6.74 %)	16.2	1.06
	Italy	4	1497 (4.75 %)	24841 (7.15 %)	16.6	1.08
	Spain	5	997 (3.16 %)	11170 (2.31 %)	11.2	0.73
North America	USA	1	9229 (29.31 %)	215259 (44.61%)	23.3	1.52
	Canada	2	1040 (3.30 %)	19628 (4.07 %)	18.9	1.23
	Mexico	3	112 (0.36 %)	683 (0.14 %)	6.1	0.40
	Cuba	4	45 (0.14 %)	298 (0.06 %)	6.6	0.43
	Bermuda	5	7 (0.02 %)	192 (0.04 %)	27.4	1.79
South America	Brazil	1	502 (1.59 %)	4774 (0.99 %)	9.5	0.62
	Argentina	2	87 (0.38 %)	1064 (0.22 %)	12.2	0.80
	Chile	3	75 (0.24 %)	675 (0.14 %)	9.0	0.59
	Venezuela	4	19 (0.06 %)	370 (0.08 %)	19.5	1.27
	Colombia	5	6 (0.02 %)	52 (0.01 %)	8.7	0.57

5.4 Country-wise Publication Efficiency (PEI)

Publication Efficiency Index (PEI) is a measure of research quality[2], it indicates whether the impact of publications in a country in a research field is compatible with the research efforts. The value of PEI >1 for a country indicates that the impact of publications is more than the research effort devoted to it for that particular country and vice versa.

Where

TNC_i = Total number of citations of country i

TNC_t = Total number of citations of all countries

TNP_i = Total number of publications of country *i* and

TNP_t = Total number of publications of all countries

The Netherlands had the highest PEI (1.93 %) followed by Switzerland with 1.68 %, USA with 1.52 %, Scotland with 1.47 %, Australia with 1.4 %, England with 1.23 %, Canada with 1.23 %, Denmark with 1.21 %, Sweden with 1.18 %, Belgium with 1.14 %, Germany with 1.1 %, Italy with 1.08 % and France with 1.06 % (Fig. 2).

Table 2. Highly productive countries in radioisotope research during 2003-2012

Rank	Country	Total publications (%)	Total citations (%)	Average citation/ publication	Publication efficiency index (*PEI*)
1	USA	9229 (29.31 %)	215259 (44.61 %)	23.3	1.52
2	Germany	2568 (8.16 %)	43 202 (8.95 %)	16.8	1.10
3	England	2344 (7.44 %)	44261 (9.17 %)	18.9	1.23
4	Japan	2194 (6.97 %)	25433 (5.27 %)	11.6	0.76
5	France	2009 (6.38 %)	32511 (6.74 %)	16.2	1.06
6	Italy	1497 (4.75 %)	24841 (5.15 %)	16.6	1.08
7	Russia	1490 (4.73 %)	7758 (1.61 %)	5.2	0.34
8	Canada	1040 (3.30 %)	19628 (4.07 %)	18.9	1.23
9	Spain	997 (3.17 %)	11170 (2.31 %)	11.2	0.73
10	Sweden	966 (3.07 %)	17498 (3.63 %)	18.1	1.18
11	Netherlands	954 (3.03 %)	28264 (5.86 %)	29.6	1.93
12	Switzerland	858 (2.72 %)	22135 (4.59 %)	25.8	1.68
13	India	828 (2.63 %)	5960 (1.24 %)	7.2	0.47
14	Peoples R China	795 (2.52 %)	7109 (1.47 %)	8.9	0.58
15	Belgium	698 (2.22 %)	12164 (2.52 %)	17.4	1.14
16	Turkey	665 (2.11 %)	4514 (0.94 %)	6.8	0.44
17	Australia	652 (2.07 %)	13999 (2.90 %)	21.5	1.40
18	South Korea	608 (1.93 %)	5366 (1.11 %)	8.8	0.58
19	Austria	532 (1.69 %)	6579 (1.36 %)	12.4	0.81
20	Brazil	502 (1.59 %)	4774 (0.99 %)	9.5	0.62

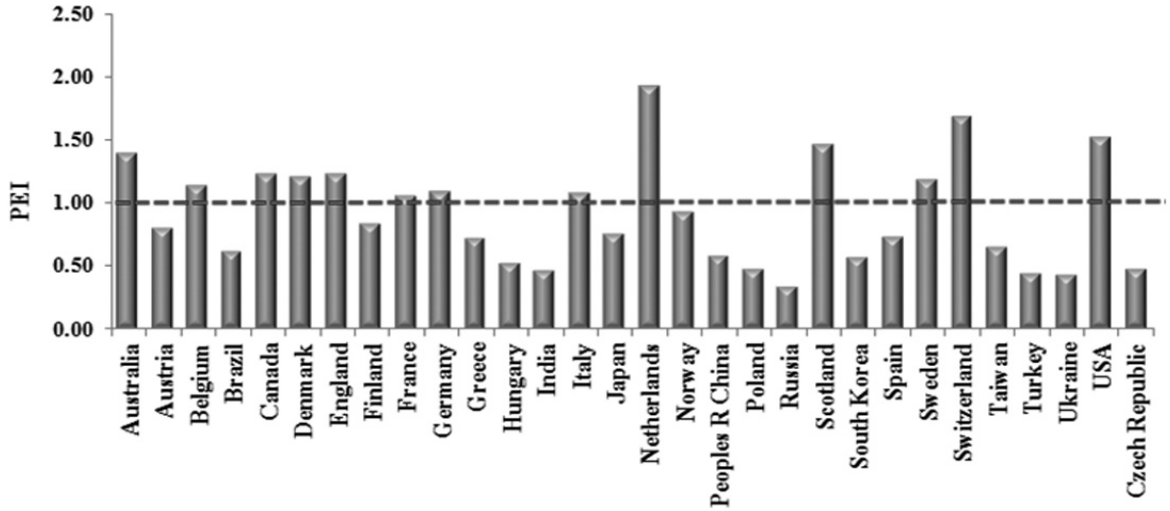

Figure 2. Publication efficiency index (PEI) of highly productive countries.

5.5 International Collaborative Index for Top Productive Countries

International collaborative index (ICI) has been taken as the proportional output of internationally co-authored papers and is an improvement over internationalisation index 7 & 8. The value of ICI = 100 indicate that a country's collaborative effort corresponds to world average. *ICI* >100 reflects collaboration higher than world average and *ICI* < 100 reflects collaboration less than world average.

Where

I_i = Number of internationally co-authored papers for country *i*

I_{io} = Total output for country *i*

i_o = Number of internationally co-authored papers for all countries

i_{oo} = Total output for all countries

Among the 30 top productive countries, 27 countries have very high values (≥100) of *ICI*. Hungary obtained the highest (109.02 %) international

collaborative index, followed by Brazil with 107.46 %, Peoples Republic of China with 107.3 %, South Korea with 107.12 %, Taiwan with 106.71 %, India with 105.81 %, Netherlands with 105.62 %, Italy with 105.18 %, Norway with 104.61 %, Japan with 104.5 %, Belgium with 103.99 %, Spain with 103.71 %, France with 103.1 %, Switzerland with 102.74 %, Sweden with 102.38 %, Canada with 102.05 % and Germany with 102 % (Fig. 34). This shows that the trend is towards more international collaboration.

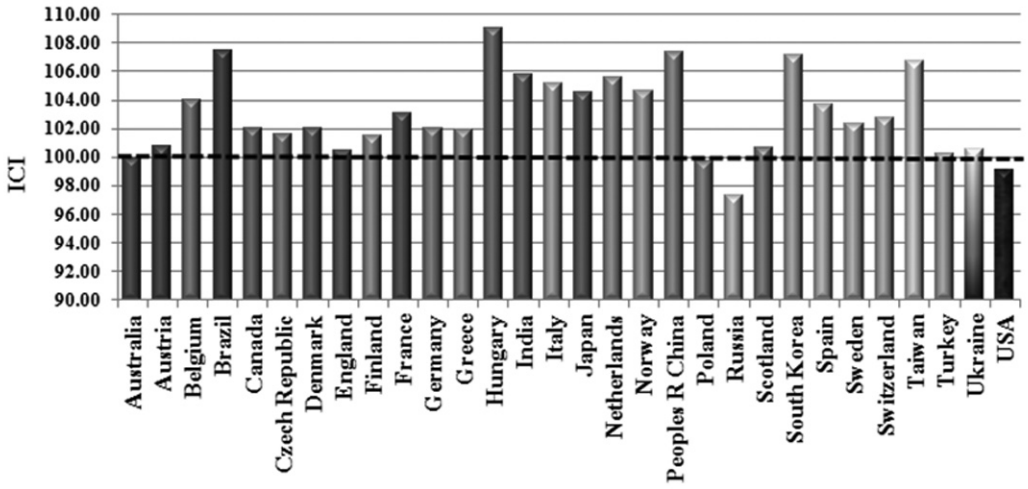

Figure 3. ICI of highly productive countries in radioisotope research during 1993-2012.

5.6 Domain-wise Distribution of Publications and Citations

Based on the classification of subject-categories in *Journal Citation Report (JCR)* of Thomson Reuters, the publication output data of radioisotope research was classified into 9 broad subjects (Fig. 4) during 1993-2012. Medical Sciences accounts for the largest share (38.14 %, 12094 papers) of publications in the total worldwide output which received 263672 (54.64 %) citations, followed by Earth & Environmental Sciences (20.69 %, 6515 papers) and 77382 (16.04 %) citations; Chemical Sciences (15.77 %, 4967 papers) and 43612 (9.04 %) citations; Engineering Sciences (7.6 %, 2393 papers) and 23913 (4.96 %) citations; Biological Sciences (7.07 %, 2227 papers) and 39594 (8.21 %) citations, Nuclear Science & Technology 238 (3.93 %, 1238 papers) and 4449 (0.92 %) citations, Physical Sciences (3.75 %, 1182 papers) and 15875 (3.29 %) citations; Food & Agriculture Sciences (1.72 %, 541 papers) and 6919 (1.43 %) citations; and Multidisciplinary Sciences (1.05 %, 331 papers) and 7133 (1.48 %) citations.

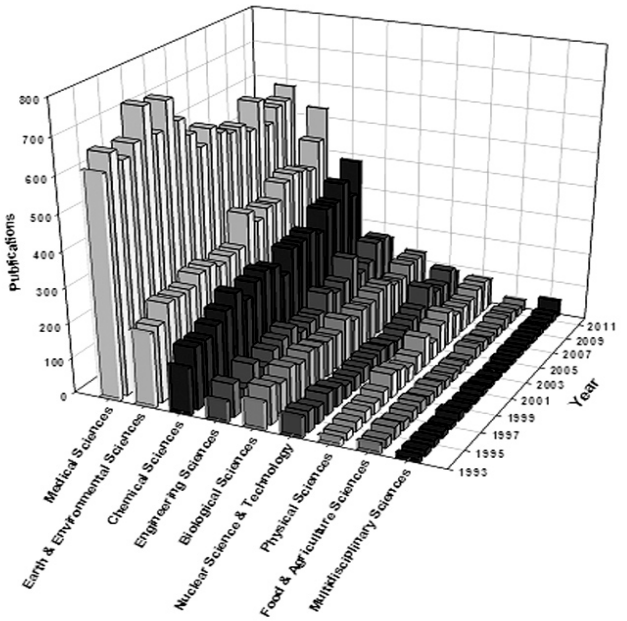

Figure 4. Year-wise and subject-wise distribution of publications in radioisotope research.

5.7 Variation of Impact Factors in Various Subjects

There are many reasons for variation in impact factor in various subjects. The number of researchers working in a field is one of the important factors, the more number of active researchers in a field tend to receive more number of citations than the field with less number of active researchers. The number of articles a journal publishes in a year, number of journals subscribed by the institutes across the world, number of citations received, differences in the time-lag between the publication and subsequent citation, fundamental and broad areas of research tend to receive more number of citations than the narrower and applied areas, coverage of journals in citation database, etc. Subject-wise average citations per publication is given in Fig. 5.

5.8 Highly Productive Institutes

Table 3 shows the institutes that have contributed 161 or more publications on radioisotopes during 1993-2012. Russian Academy of Science, Russia

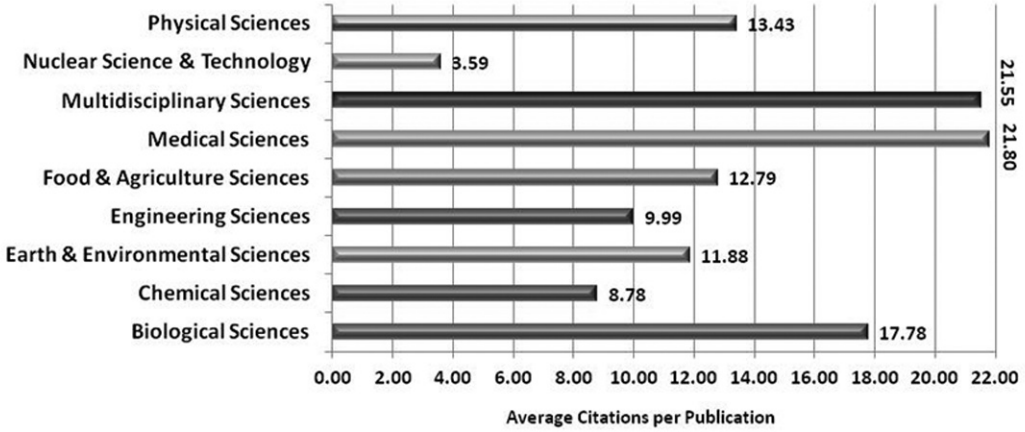

Figure 5. Subject-wise average citations per publication.

Table 3. Highly productive institutes with publications (≥161) on radioisotopes research

Rank	Institutes	TP	TC	ACP	TIF	AIF
1	Russian Academy of Sciences, Russia	429	1530	3.57	377.2	0.88
2	Atomic Energy Alternative Energies Commission CEA, France	396	5029	12.70	758.85	1.92
3	Bhabha Atom Research Centre, India	284	1913	6.74	448.28	1.58
4	Pacific Northwest National Laboratory, USA	282	5274	18.70	728.17	2.58
5	National Institutes of Health (NIH), USA	252	6609	26.23	1170.37	4.64
6	Harvard University, USA	247	8223	33.29	1221.29	4.94
7	Oak Ridge National Laboratory, USA	228	4549	19.95	525.17	2.30
8	International Atomic Energy Agency, Austria	219	2630	12.01	446.27	2.04
9	Lawrence Berkeley National Laboratory, USA	218	4244	19.47	609.69	2.80
10	Mayo Clinic & Mayo Foundation, USA	188	7467	39.72	1129.19	6.01
10	University of California, Berkeley, USA	188	3409	18.13	522.57	2.78
11	Korea Atom Energy Research Institute, South Korea	187	756	4.04	267.57	1.43
12	Memorial Sloan Kettering Cancer Center, USA	183	7830	42.79	821.15	4.49
13	National Institute of Radiological Science, Japan	182	1701	9.35	326.44	1.79
14	University of Washington, Seattle, USA	181	5755	31.80	760.27	4.20
15	Paul Scherrer Institute, Switzerland	180	2931	16.28	411.28	2.28
16	Washington University, St Louis, USA	176	6356	36.11	857.64	4.87
17	Duke University, USA	175	6031	34.46	774.67	4.43
18	University of Michigan, USA	172	5249	30.52	836.99	4.87
19	Uppsala University, Sweden	170	3147	18.51	606.5	3.57
20	Technical University of Munchen, Germany	169	3531	20.89	692.33	4.10
21	Los Alamos National Laboratory, USA	161	2129	13.22	316.34	1.96

TP = Total papers; TC = Total citations; ACP = Average citations per paper; TIF = Total impact factor; AIF = Average impact factor

topped the list with 429 publications with 3.57 average citations per publication, followed by Atomic Energy Alternative Energies Commission CEA, France with 396 publications and 12.7 citations per publication, Bhabha Atomic Research Centre, India with 284 publications and 6.74 citations per publication, Pacific Northwest National Laboratory with 282 publications and 18.7 citations per publication and National Institutes of Health (NIH), USA with 252 publications and 26.23 citations per publication.

5.9 Quality of Research Output

90.9 % (28624) of the total publications were published in the journals with impact factors (IF) ranging from 00.01 to 153.46 and received 92.32 % (445480) citations, and 9.10 % (2864) publications published in journals having without impact factor. Table 4 gives distribution of publications and citations according to impact factor range of journal publications. It is revealed from the Table that the highest number of publications

Table 4. Distribution of publications and citations as per impact factor range

Impact factor (*JCR 2010*)	Total journals	Total papers (TP) (%)	Total citations (TC) (%)	Average citations/paper (ACP)
0.01 to ≤ 1.00	709	4464 (14.18)	15486 (3.21)	3.47
1.01 to ≤ 2.00	764	9553 (30.34)	80204 (16.62)	8.40
2.00 to ≤ 3.00	598	6071 (19.28%)	86170 (17.86)	14.19
3.00 to ≤ 4.00	339	3307 (10.50)	63077 (13.07)	19.07
4.00 to ≤ 5.00	158	1245 (3.95)	30673 (6.36)	24.64
5.00 to ≤ 6.00	93	2034 (6.46)	57113 (11.84)	28.08
6.00 to ≤ 7.00	53	630 (2.0)	25564 (5.30)	40.58
7.00 to ≤ 153.46	130	1320 (4.19)	87193 (18.07)	66.06
Without IF	547	2864 (9.10)	37069 (7.68)	12.94
Total	**3391**	**31488 (100)**	**482549 (100)**	**15.32**

(9553, 30.34 %) appeared in 764 journals having impact factor range from 1.01 to ≤2.00 and received 80204 (16.62 %) citations with 8.40 average citation per publication.

5.10 Journals Preferred for Publication by the Scientists

The scientific literature on radioisotopes is spread over 3391 different source journals. More than 60 % of the publications are published in only 173 key-journals. Table 5 gives the leading journals each with impact factor, number of publications, number of citations, and average citations per publication. The highly productive journals are: *Journal of Environmental Radioactivity* with 1220 (3.87 %) publications, *Journal of Radioanalytical and Nuclear Chemistry* 1218 (3.87 %); *Applied Radiation and Isotopes* 1128 (3.58 %); *Radiation Protection Dosimetry* 784 (2.49 %); *Journal of Nuclear Medicine* 777 (2.47 %); *Health Physics-*

Table 5. Preference of journals for publication in radioisotope research

Journal	Impact factor-2012	Total publications (TP) (%)	Cumulative % of TP	Total citations (%)
Journal of Environmental Radioactivity	2.12	1220 (3.87)	3.87	13324 (2.76)
Journal of Radioanalytical and Nuclear Chemistry	1.47	1218 (3.87)	7.74	5711 (1.18)
Applied Radiation and Isotopes	1.18	1128 (3.58)	11.32	9004 (1.87)
Radiation Protection Dosimetry	0.91	784 (2.49)	13.81	3670 (0.76)
Journal of Nuclear Medicine	5.77	777 (2.47)	16.28	24242 (5.02)
Health Physics	1.02	662 (2.10)	18.38	5133 (1.06)
Radiochimica Acta	1.37	487 (1.55)	19.93	4762 (0.99)
Nuclear Instruments & Methods in Physics Research-A	1.14	436 (1.38)	21.31	3118 (0.65)
Science of the Total Environment	3.26	411 (1.31)	22.62	5779 (1.20)
Nuclear Medicine Communications	1.38	391 (1.24)	23.86	3310 (0.69)
Nuclear Instruments & Methods in Physics Research-B	1.27	368 (1.17)	25.03	3974 (0.82)
Clinical Nuclear Medicine	2.96	333 (1.06)	26.09	2035 (0.42)
European Journal of Nuclear Medicine and Molecular Imaging	5.11	302 (0.96)	27.05	6050 (1.25)
Nuclear Medicine and Biology	2.52	244 (0.77)	27.82	4225 (0.88)
Journal of Nuclear Cardiology	2.85	242 (0.77)	28.59	3634 (0.75)
Cancer Biotherapy and Radiopharmaceuticals	1.74	240 (0.76)	29.35	3031 (0.63)
Radiology	6.34	221 (0.70)	30.05	12395 (2.57)
Circulation	15.20	212 (0.67)	30.72	20143 (4.17)
European Journal of Nuclear Medicine	0.00	210 (0.67)	31.39	9676 (2.01)
Environmental Science & Technology	5.26	200 (0.64)	32.03	4884 (1.01)

Cont...

Medical Physics	2.91	183 (0.58)	32.61	2558 (0.53)
Journal of Radioanalytical and Nuclear Chemistry-Articles	0.00	178 (0.57)	33.18	1243 (0.26)
Atomic Energy	0.03	176 (0.56)	33.74	53 (0.01)
American Journal of Cardiology	3.21	173 (0.55)	34.29	4628 (0.96)
Journal of the American College of Cardiology	14.09	164 (0.52)	34.81	13249 (2.75)
Physics in Medicine and Biology	2.70	164 (0.52)	35.33	1975 (0.41)
Radiation Measurements	0.86	153 (0.49)	35.82	1418 (0.29)
IEEE Transactions on Nuclear Science	1.22	149 (0.47)	36.29	1095 (0.23)
Journal of Urology	3.70	146 (0.46)	36.75	3946 (0.82)
Journal of Nuclear Science and Technology	1.03	142 (0.45)	37.20	597 (0.12)
Seminars in Nuclear Medicine	3.82	139 (0.44)	37.64	3762 (0.78)
Journal of Contaminant Hydrology	2.89	138 (0.44)	38.08	2592 (0.54)
Quarterly Journal of Nuclear Medicine	0.00	133 (0.42)	38.50	2731 (0.57)
Nuclear Technology	0.45	132 (0.42)	38.92	515 (0.11)
Quarterly Journal of Nuclear Medicine and Molecular Imaging	1.92	126 (0.40)	39.32	1261 (0.26)

662 (2.1 %) publications, Radiochimica Acta with 487 (1.55 %) publications, *Nuclear Instruments & Methods In Physics Research*-A with 436 (1.38 %) publications, *Science of the Total Environment* with 411 (1.31 %) publications and *Nuclear Medicine Communications* with 391 (1.24 %) publications.

5.11 Highly Cited Publications

The highly cited 10 radioisotopes publications (which have got at least 500 citations) during the period of study are listed in Table 6. The most frequently cited one was "Pankhurst, Q.A.; *et al*. Applications of magnetic nanoparticles in

Table 6. Highly cited publications in radioisotope research

Rank	Bibliographic details	Journal IF 2012	Times cited	Document type	Author(s) in By-line
1	Pankhurst, Q.A.; *et al*. Applications of magnetic nanoparticles in biomedicine. *J Phys D Appl Phys* (2003). Vol. 36 (13): pp. R167-R181	2.53	2050	Review	4
2	Pound, C.R.; *et al*. Natural history of progression after psa elevation following radical prostatectomy. *JAMA-J Am Med Assoc* (1999). Vol. 281 (17): pp. 1591-1597	29.98	1486	Article	6
3	Grines, CL; *et al*. A comparison of immediate angioplasty with thrombolytic therapy for acute myocardial-infarction. *New Engl J Med* (1993). Vol. 328 (10): pp. 673-679	51.66	1418	Article	14
4	Strauer, B.E.; *et al*. Repair of infarcted myocardium by autologous intracoronary mononuclear bone marrow cell transplantation in humans. *Circulation* (2002). Vol. 106 (15): pp. 1913-1918	15.20	1219	Article	8
5	Krenning, E.P.; *et al*. Somatostatin receptor scintigraphy with [in-111-dtpa-d-phe(1)]- and [i-123-tyr(3)]-octreotide - the rotterdam experience with more than 1000 patients. *Eur J Nucl Med* (1993). Vol. 20 (8): pp. 716-731	0.00	1096	Review	15
6	Zijlstra, F.; *et al*. A comparison of immediate coronary angioplasty with intravenous streptokinase in acute myocardial-infarction. *New Engl J Med* (1993). Vol. 328 (10): pp. 680-684	51.66	830	Article	6
7	Cohn, J.N.; *et al*. Cardiac remodeling-concepts and clinical implications: a consensus paper from an international forum on cardiac remodeling. *J Am Coll Cardiol* (2000). Vol. 35 (3): pp. 569-582	14.09	721	Review	3

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8	Singal, P.K. & Iliskovic, N. Doxorubicin-induced cardiomyopathy. *New Engl J Med* (1998). Vol. 339 (13): pp. 900-905	51.66	713	Review	2
9	Cody, R.B.; *et al*. Versatile new ion source for the analysis of materials in open air under ambient conditions. *Anal Chem* (2005). Vol. 77(8): pp. 2297-2302	5.70	667	Article	3
10	Stone, J.O. Air pressure and cosmogenic isotope production. *J Geophys Res-Sol Ea* (2000). Vol. 105 (B10): pp. 23753-23759	0.00	584	Article	1

biomedicine. *J Phys D Appl Phys* (2003). Vol. 36 (13), pp. R167-R181" with 2050 citations. Out of 10 highly cited publications, 6 are journal articles and 4 are review articles.

6. CONCLUSIONS

Radioisotopes play a very predominant role in healthcare, industry, food and agriculture, and environmental monitoring, etc. A lot of research is being carried out all over the world in this field. A total of 31488 publications were published on radioisotopes during 1993-2012 and these publications received 482549 citations. The highest number of publications 2036 (6.47 %) were published in 2012. The highest number of citations 33316 (6.90 %) were received in 1999. The highest average citations per publication was 24.77 in 1993. There were 4421 (14.04 %) publications with no citations during the period under study. Overall collaboration rate (CR) was very high (0.91) as 28729 (91.21 %) publications of the total documents were multi-authored and the highest collaboration rate (0.94) was in 2010 and 2011 respectively indicates that the trend is towards more number of multi-authored collaborative publications. An exponential growth of publications was observed in this study.

It was observed that Europe is the most productive continent with 18267 (46.75 %) publications and 296158 (46.70 %) citations followed by North America with 10444 (26.73 %) publications and 236167 (37.24 %) citations and Asia with 8202 (20.99 %) publications and 71044 (11.2 %) citations.

The USA topped the list with highest share (29.31 %) of publications. Germany ranked second with 8.16 % share of publications followed by England with 7.44 % share of publications, Japan with 6.97 % share of publications Netherlands had the highest PEI (1.93 %) followed by Switzerland with 1.68 %, USA with 1.52 %, Scotland with 1.47 %, Australia with 1.4 %, England with 1.23 % and Canada with 1.23.

Hungary had the highest (109.02 %) international collaborative index followed by Brazil with 107.46 %, Peoples R China with 107.3 %, South Korea with 107.12 %, Taiwan with 106.71 % and India with 105.81 % indicates that these countries more international collaboration in this field.

Medical Sciences accounts for the largest share 12094 (38.14 %) of publications in the total worldwide output which received 263672 (54.64 %) citations followed by Earth & Environmental Sciences with 6515 (20.69 %) publications and 77382 (16.04 %) citations, Chemical Sciences with 4967 (15.77 %) publications and 43612 (9.04 %) citations, Engineering Sciences with 2393 (7.6 %) publications and 23913 (4.96 %) citations, Biological Sciences with 2227 (7.07 %) publications and 39594 (8.21 %) citations and Nuclear Science & Technology with 1238 (3.93 %) publications and 4449 (0.92 %) citations.

Russian Academy of Sciences-Russia topped the list with 429 publications and 3.57 average citations per publication followed by Atomic Energy Alternative Energies Commission CEA-France with 396 publications and 12.7 citations per publication and Bhabha Atomic Research Centre-India with 284 publications and 6.74 citations per publication.

90.9 % (28624) of the total publications were published in the journals with impact factors (IF) ranging from 00.01 to 153.46 and received 92.32 % (445480) citations, and 9.1 % (2864) publications were published in journals having zero impact factor.

The scientific research in radioisotopes is spread over 3391 different journals. More than 60 % of the publications were published in only 173 key-journals, indicates that they are the core journals where the important research results are published.

REFERENCES

1. Garg, K.C. & Padhi, P. A study of collaboration in laser science and technology, *Scientometrics*, 2001, **51**, 415-27.
2. Guan, J. & Ma, M. A Bibliometric study of China's semiconductor literature compared with other major Asian countries, *Scientometrics*, 2007, **70**(1), 107-24.
3. Kademani, B.S.; Kumar, V.; Sagar, A. & Kumar, A. Scientometric dimensions of nuclear science and technology research in India: A study based on INIS (1970- 2002) database, *Malaysian J. Lib. and Inf. Sci.*, 2006, **11**(1), 21-46.
4. Kademani, B.S.; Kumar, V.; Sagar, A.; Kumar, A.; Mohan, L. & Surwase, G. Scientometric

dimensions of thorium research in India, *DESIDOC Bull. Lib. & Inf. Technol.*, 2006, **26**(3), 9-25.
5. Kademani, B.S.; Kumar, V.; Sagar, A. & Kumar, A. World literature on thorium research: A scientometric study based on Science Citation Index, *Scientometrics*, 2006, **29**(2), 347-64.
6. Kademani, B.S.; Surwase, G. & Bhanumurthy, K. Zirconium research in nuclear science and technology: A scientometric perspective, *Int. J. Nucl. Knowl. Manag.*, 2011a, **5**(4), 386-401.
7. Nagpaul, P.S. Transnational linkages of Indian science: A structural analysis, *Scientometrics*, 1999, **46**, 109-40.
8. Sagar, A.; Kademani, B.S.; Garg, R.G. & Kumar, V. Research trends in Cobalt-60 in nuclear science and technology, *Int. J. Nucl. Knowl. Manag.*, 2010, **4**(2), 146-64.

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