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Research Focus and Trends in Nuclear Science and Technology in Ghana: A Bibliometric Study Based on the INIS Database

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RESEARCH FOCUS AND TRENDS IN NUCLEAR SCIENCE AND TECHNOLOGY IN GHANA: A BIBLIOMETRIC STUDY BASED ON THE INIS DATABASE

Abstract

The peaceful application of atomic energy was introduced into Ghana about fifty years ago. This is the first bibliometric study of nuclear science and technology research publications originating from Ghana and listed in the International Nuclear Information System (INIS) Database. The purpose was to use the simple document counting method to determine the geographical distribution, annual growth and the subject areas of the publications as well as communication channels, key journals and authorship trends. The main findings of the study were that, a greater number of the nuclear science and technology records listed in the Database were published in Ghana (598 or 56.57% against 459 or 43.43% published outside Ghana). There has been a steady growth in the number of publications over the years with the most productive year being 2012. The main focus of research has been in the area of applied life sciences, comprising plant cultivation & breeding, pest & disease control, food protection and preservation, human nutrition and animal husbandry; followed by chemistry; environmental sciences; radiation protection; nuclear reactors; physics; energy; and radiology and nuclear medicine. The area with the least number of publications was safeguards and physical protection. The main channel of communicating research results was peer reviewed journals and a greater number of the journal articles were published in Ghana followed by the United Kingdom, Hungary and the Netherlands. The core journals identified in this study were *Journal of Applied Science and Technology*; *Journal of Radioanalytical and Nuclear Chemistry*; *Journal of the Ghana Science Association*; *Radiation Protection Dosimetry*; *Journal of the Kumasi University of Science and Technology*; *West African Journal of Applied Ecology*; *Ghana Journal of Science*; *Applied Radiation and Isotopes*; *Annals of Nuclear Energy*, *IOP Conference Series (Earth and Environmental Science)* and *Radiation Physics and Chemistry*. Eighty percent of the journal articles were by multiple authors with three authored papers forming the majority. The study will be useful in evaluating research performance and also serve as a foundation for other African countries engaged in the peaceful applications of nuclear science and technology.

Keywords

Bibliometrics, Scientometrics, Ghana, Nuclear science and Technology, International Nuclear Information System, Publication output, Communication channels.

1. Introduction

Fifty years ago, in November 1964, the foundation stone for the Ghana Nuclear Reactor Project was laid by Osagyefo Dr Kwame Nkrumah, the first President of the Republic of Ghana. Prior to this historic event, the law establishing the Ghana Atomic Energy Commission (GAEC) was promulgated in 1963 (Act 204) with the mandate to promote, develop and utilise the peaceful application of nuclear techniques for the social, economic, scientific and technological progress of Ghana. It is significant to note the increase in the Country's nuclear research and development activities with the passage of time. Five nuclear related research institutes currently operating under the GAEC are the National Nuclear Research Institute; the Biotechnology and Nuclear Agriculture Research Institute; the Radiation Protection Institute; the Radiological and Medical Sciences Research Institute and the Ghana Space Science and

Technology Institute. Moreover in 2006, the GAEC in collaboration with the International Atomic Energy Agency and the University of Ghana established the Graduate School of Nuclear and Allied Sciences. The Country's public universities have also incorporated nuclear science and technology into their academic programmes. In operation are several nuclear facilities, the major ones being the GHARR-1 Research Reactor, the Gamma Irradiation Facility, and two Radiotherapy Centres.

It has been fifty long years since the introduction of nuclear science and technology in Ghana. Many resources; both material and human have been channeled into this area by the government. Moreover, Ghana has received substantial support from the International Atomic Energy Agency through its technical cooperation programme for less-developed countries, especially in the areas of agriculture; human health; safety; water and environment; education and industry. Therefore, it is appropriate at this stage, to take stock of the Country's nuclear science and technology research output in terms of scientific publications. This is the first time that such a study is being conducted in the nuclear sector in Ghana. The results will contribute to the management of research in nuclear science and technology and also serve as a basis for further bibliometric studies in nuclear science and technology in Ghana and other parts of Africa.

2. Literature Review

There are several quantifiable scientific research activities, the most common being the number of publications, which may be used as a measure of research output (Thomson Reuters, 2008). Okubo (1997), Schubert and Telcs (1986) and others, also share the view that the study of the publication output in any field is a good indicator of the state of research in that field. This is particularly true for African countries that do not have proper systems for monitoring science and technology (Pouris and Pouris (2004).

Bibliometrics, also known as scientometrics is a research technique in library and information science that applies quantitative analysis and statistics to describe publication patterns in any field of knowledge. It is usually used to assess national research profiles, regional patterns of research and collaboration within research groups (Thanuskodi 2010). Thomson Reuters (2008) recommend that results of such studies can be used by librarians to confirm the research performance of their organizations and also identify key journals and gaps in the library collection. Public relations practitioners may find tangible figures about research results handy in their reportage. Research administrators may also find results of such studies useful in evaluating research performance, annual reporting, and allocation of funds as well as in making staffing decisions. Moreover, subject specialists and researchers can also use bibliometrics to analyse their own subject fields and also decide on where to publish.

A lot of bibliometric studies have been conducted in science and technology and of relevance to this study are previous bibliometric studies that used the INIS Database as a data source. Some of the studies have been on specific subject fields at the global level, others have also analysed the literature of specific countries. Examples of bibliographic studies on specific subjects in nuclear science and technology at the global level are condensed matter physics and fusion research and technology (Hillebrand, 1999a-b); neutron activation analysis (Sagar, Kademani and Kumar, 2009); fast breeder power reactors (Marinkovic, 2001) research reactors (Marinkovic, 2002); cobalt 60 (Sagar, Kademani, Garg & Kumar,

2010); radioisotopes (Sagar et al, 2012); radioactive waste management (Kademani et al., 2013); Chernobyl accident (Negeri 2005); Radiology and Nuclear medicine (Zeraatkar, 2013); fuel cell research (Girap et al., 2011) and nuclear power generation (Venkatesan and Thanuskodi, 2014).

Directly related to the present study are bibliometric studies of the nuclear literature of specific countries, which unfortunately are limited. In a major work, Kademani et al. (2006) investigated the growth and development of nuclear science and technology research in India based on their publication output from 1970 to 2002 with the INIS Database as a data source. They observed a high level of local and international collaboration in India and also noted that the main channel of communicating research results was peer reviewed journals and that over 60% of the Indian records in the INIS Database were journal articles

In Mexico, Garrido (2007) reviewed the nuclear research output in terms of publications using 920 nuclear science papers published between 1986 and 1994. Unlike the aforementioned study in India that used data from the INIS Database only, this study combined bibliographic references from the INIS Database as well as proceedings and annual reports listed elsewhere. The papers were analysed by subject, institutions, authors, co-authorship, publication year, publishing journals, geographic origin and language of publication.

Using the survey and citation analysis method, Akbari and Bozorgi (2009) analysed Iranian records in the INIS Database from 2002 to 2006. They compared the citation behavior of the authors, and also determined the core journals used for publishing research findings. The results revealed that, there were 4,351 citations in 300 articles with an average of 14.5 citations per article. The main subject area was nuclear medicine and radiology. Three key journals, namely, “Physics Review”, “Physics Review Letters” and “Physica” were identified.

More recently, Davarpanah (2012) undertook a quantitative and qualitative assessment of the status of nuclear science and technology in Iran. Whereas the studies mentioned above used the INIS Database as a data source, this study was based on data obtained from the Science Citation Index Expanded from 1990 to 2010. He observed the exponential growth of Iranian nuclear literature and the strong emphasis on physics and chemistry. The study also revealed that academic institutions are the main source of the country’s nuclear literature and that they preferred to publish in three journals, namely, *Annals of Nuclear Energy*, *Physical Review C* and *Nuclear Physics A*. Three types of authorship namely single author, national co-authorship, and international co-authorship identified. A significant finding of the study was that, 93% of the papers were by multiple authors and there was a high level of local and international collaboration in Iran.

In Denmark, Van Leeuwen and Tussen (1993) did a quantitative study of Dutch nuclear energy research literature by combining data from the Institute for Scientific Information (ISI) and non ISI databases to describe the state of affairs of nuclear energy research in the 1980’s. They noted the value of combining bibliometric indicators of publication output, international visibility and international co-operation in a study of nuclear energy research.

From the literature so far reviewed, it is obvious that there is a dearth or perhaps non-existence of bibliometric studies in nuclear science and technology research in Africa, hence the need to conduct this study in Ghana to fill this gap in the nuclear information literature.

3. Research Questions

This study aims at investigating the publishing trends in nuclear science and technology in Ghana using the International Nuclear Information System (INIS) Database. It specifically seeks to answer the following questions about nuclear science and technology research publications in Ghana:

1. Where do nuclear researchers in Ghana publish their work?
2. What is the growth rate of the nuclear science and technology publications?
3. What are the main subject areas of nuclear research?
4. What are the preferred channels of communicating nuclear science and technology research results?
5. What is the authorship trend in nuclear science and technology?

4. Methodology

In this study, the descriptive bibliometric technique was used to analyse Ghanaian publications listed in the INIS Database for the past 50 years starting from 1964, when the peaceful applications of nuclear science and technology was introduced in Ghana, to the current year, 2014. The INIS Database on the Internet was considered to be suitable for the study because of its specialized nature; the subject scope being the peaceful aspects of nuclear science and technology. Moreover, the Online version of the Database enables filtering of queries by specific fields such as country, year, type and subject of publication.

The main criterion for inclusion of the Database records in the analysis was that, the research project must have been undertaken in Ghana irrespective of the nationality of the author or place of publication. Based on this condition, the main search term used was “Ghana”. The search was initially limited to the “Author Field” which contains names of authors, their affiliated organizations and addresses including country names or codes. By this way, 840 records with personal authors affiliated to Ghanaian institutions or organizations were retrieved. To ensure comprehensiveness of coverage, the search term “Ghana” was then limited to the “Corporate Author” and “Record Type” fields to retrieve records with corporate author entries such as academic theses, and legislative material. All records retrieved were then exported to Microsoft Excel. After checking and deleting duplicate entries, a total of 1057 records remained for the analysis. Kademi et al. (2006) used a similar method to assess nuclear science and technology research in India. The results were presented and illustrated with simple frequencies, percentages, graphs and charts.

5. Results and Discussion

5.1 Where Do Nuclear Researchers In Ghana Publish the Results of their Work?

Presented in Table 1 is the distribution of the records by country of publication. Overall, the records were published in 29 countries including one international organisation. It was observed that more than half of the publications (598 or 56.57%) were published in Ghana and the rest (459 or 43.43%) were published outside Ghana. The International Atomic Energy Agency (IAEA) had the second largest share of publications with 19.96% (211), which was expected, considering the fact that, every year it organizes several conferences and workshops and publishes its own conference proceedings and other technical documents. The United Kingdom followed with 10.8% (115) publications. Perhaps, this could be attributed to the historical ties between the two countries; Hungary followed with 3.78 (40) publications; Netherlands with 1.89% (20); United States with 1.32% (14); Germany with 1.04% (11); and India with 0.66% (7). Surprisingly, the share of the publications in other parts of Africa was less than 1% (Nigeria 0.47% (5) and Egypt 0.18% (2)). Overall, the total count of the publications in developing countries, Africa, was found to be negligible.

Table 1: Distribution of Ghanaian Publications by Country/International Organisation

Country/organization	No. of publications	Percentage	Country/organization	No. of publications	Percentage
Ghana	598	56.57	Italy	2	0.18
IAEA	211	19.96	Japan	2	0.18
United Kingdom	115	10.87	Pakistan	2	0.18
Hungary	40	3.78	Poland	2	0.18
Netherlands	20	1.89	United Nations	2	0.18
U. S. A.	14	1.32	Argentina	1	0.09
Germany	11	1.04	Austria	1	0.09
India	7	0.66	Belgium	1	0.09
Nigeria	5	0.47	Denmark	1	0.09
Brazil	4	0.37	Ireland	1	0.09
Australia	3	0.28	Israel	1	0.09
China	3	0.28	Kenya	1	0.09
France	3	0.28	Slovenia	1	0.09
Egypt	2	0.18	Sweden	1	0.09
FAO	2	0.18			

5.2 What is the Growth Rate of the Nuclear Science and Technology Research Publications?

The annual distribution of the publications is shown in Table 2a. It is worth noting that, the rate of growth of the publications fluctuated until the year 2008 when the growth became fairly steady. It was also observed that, the most productive year was 2012 with 98 (9.2%) publications, followed by 2013 with 90 (8.51%) publications, 2010 with 89 (8.42%) publications and 2011 with 75 (7.09%) publications. The very low figure recorded for the year 2014 was not surprising since the present study was conducted in that year, therefore records for that year were yet to be published or added to the INIS Database. Overall, the average number of publications per year was 20.72

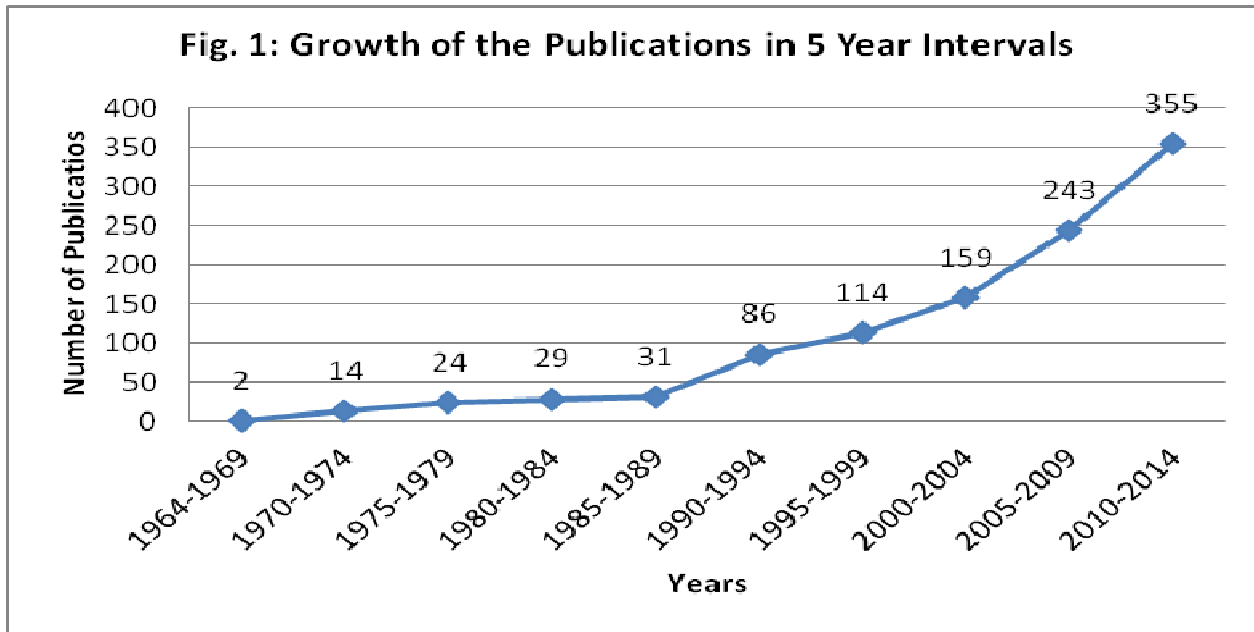
Table 2a: Distribution of Ghanaian Records in the INIS Database by Year of Publication

YEAR OF PUBLICATION	NO. OF RECORDS	PERCENTAGE (%)	YEAR OF PUBLICATION	NO. OF RECORDS	PERCENTAGE (%)
1964	1	0.09	1990	11	1.04
1965	0	0.00	1991	13	1.22
1966	0	0.00	1992	9	0.85
1967	0	0.00	1993	14	1.32
1968	1	0.09	1994	39	3.68
1969	0	0.00	1995	26	2.45
1970	2	0.18	1996	7	0.66
1971	4	0.37	1997	34	3.21
1972	2	0.18	1998	20	1.87
1973	3	0.28	1999	27	2.55
1974	3	0.28	2000	17	1.6
1975	7	0.66	2001	35	3.31
1976	6	0.56	2002	22	2.08
1977	1	0.09	2003	44	4.16
1978	7	0.66	2004	41	3.87
1979	3	0.28	2005	33	3.12
1980	9	0.85	2006	34	3.21
1981	12	1.13	2007	42	3.97
1982	6	0.56	2008	59	5.58
1983	1	0.09	2009	75	7.09
1984	1	0.09	2010	89	8.42
1985	4	0.37	2011	75	7.09
1986	4	0.37	2012	98	9.32
1987	5	0.47	2013	90	8.51
1988	5	0.47	2014	3	0.28
1989	13	1.22			

The publishing trend becomes more comprehensible when the publication years are aggregated into 5-year clusters as depicted in Table 2b and Figure 1 below. Starting with only two publications in the early years (1964-1969), the growth in the number of publications over the years is seen, with the most productive years being the current period from 2010 to 2014 with 355 papers, representing 33.58% of the total, with a yearly average of 71 publications. The period from 2005 to 2009 followed with 243 papers. The highest growth rate (600%) was recorded during 1970 to 1974 and the lowest growth rate was recorded during 1985 to 1989. The average growth rate was 105.3%. The growth in the Ghanaian nuclear literature in recent years may be attributed to several factors, among which are the increase in nuclear research and development activities resulting in the recruitment of more research scientists in the nuclear sector; promotion which is an incentive for publishing, Internet publishing; and increase in the Country's input to the INIS Database.

Table 2b: Growth rate of the publications in five-year intervals

YEARS	NO. OF PUBLICATIONS	% OF PUBLICATIONS	% GROWTH RATE
1964-1969	2	0	0.0
1970-1974	14	1	600.0
1975-1979	24	2	71.4
1980-1984	29	3	20.8
1985-1989	31	3	6.9
1990-1994	86	8	177.4
1995-1999	114	11	67.4
2000-2004	159	15	10.4
2005-2009	243	23	52.8
2010-2014	355	34	46.0
TOTAL	1057	100	105.3 (Average)



5.3. What Are The Main Subject Areas Of Nuclear Science And Technology Research in Ghana?

The subject areas of the records used in the analysis were based on the INIS/ETDE Subject Categories and Scope Descriptions (IAEA, 2002). It should be noted that some of the records listed in the Database contained more than one INIS assigned subject category but in the present study, only the primary subject categories were used in the analysis, and for convenience, a few of the subject categories that are closely related were combined.

Table 3 below shows the subject distribution of the publications. This illustrates the scope of the Country's nuclear science and technology programme. The subject area with the highest number of publications is Applied Life Sciences with 228 (21.5%) publications. The Country's nuclear programme in this area includes plant cultivation & breeding; pest & disease control; food protection, preservation and human nutrition; and animal husbandry. The relatively high publication count in this area was expected because agriculture continues to be the main-stay and backbone of the Ghanaian economy and, like other developing countries a lot of human and material resources are channeled into this sector. Chemistry, including radiochemistry and nuclear chemistry, followed with 135 (12.77%) publications, Environmental Sciences with 125 (11.8%), Radiation Protection and Dosimetry with 111 (10.5%) and Nuclear Reactors with 99 (9.6%) publications. Others are Energy with 68 (6.43%), Physics 63 (5.96%), Radiology & Nuclear Medicine 49 (4.63%), Isotopes and Radiation Sources 36 (3.4%), Materials Science 30 (2.83%) and Instrumentation 22 (2.07%). The area with the least number of publications is Nuclear Safeguards and Physical Protection with only 6 publications (0.56). The low count recorded for the latter could be attributed to the sensitive nature of the subject. Perhaps some of the work in this area remains unpublished for confidential reasons.

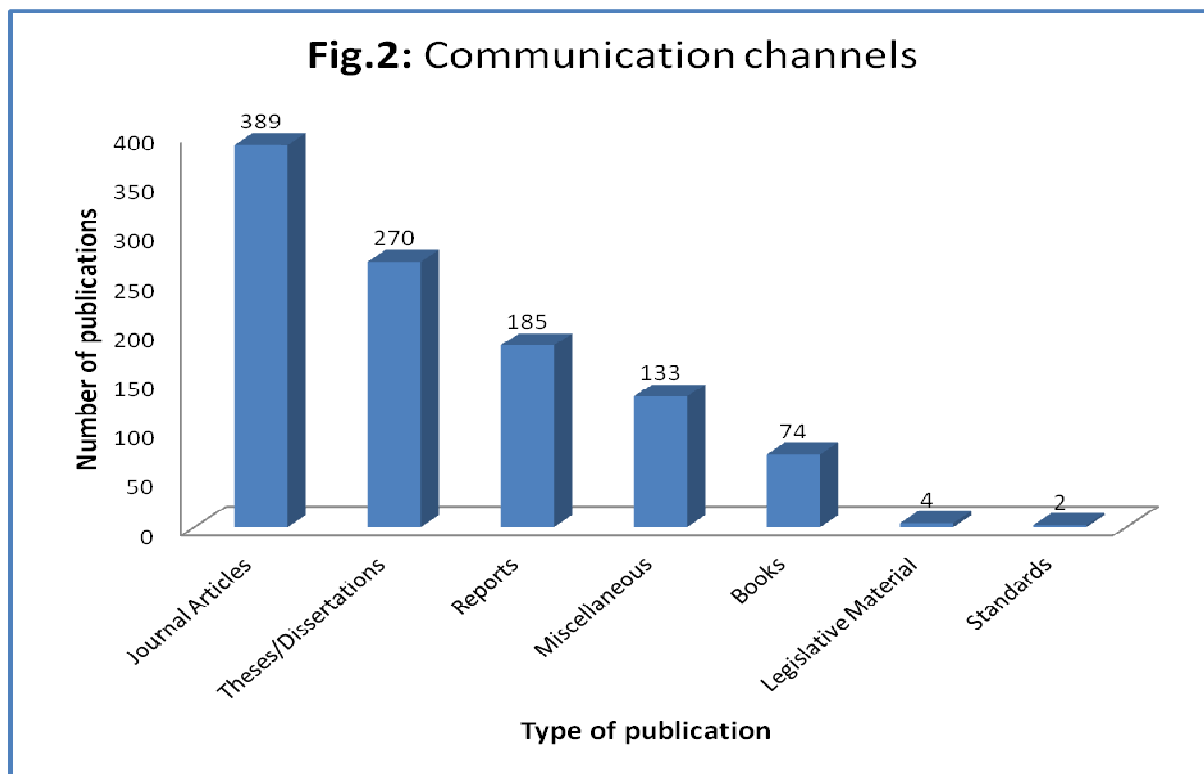
TABLE 3: Distribution of publications by subject area

Subject areas	No. of publications	Percentage (%)
Applied Life Sciences	228	21.5
Chemistry	135	12.77
Environmental sciences	125	11.82
Radiation protection	111	10.5
Nuclear reactors	99	9.36
Other aspects of nuclear & non-nuclear energy	68	6.43
Physics	63	5.96
Radiology and nuclear medicine	49	4.63
Geosciences	42	3.97
Isotopes and radiation sources	36	3.4
Materials science	30	2.83
Nuclear instrumentation	22	2.07
Management of radioactive & non-radioactive wastes	14	1.32
Engineering	14	1.32
Administration, documentation, and computation)	8	0.75
Safeguards and physical protection	6	0.56
Total	1057	100.00

5.4 What Are the Preferred Channels of Communicating Nuclear Research Results?

The study sought to determine the various communication channels used by the nuclear science and technology researchers in Ghana, and also determine the preferred channel used to present research results. This was not a difficult task because in the INIS Database, the record type for each entry is specified so it was easy to group them. According to the results, as shown in Fig. 2, the most popular channel was peer reviewed Journals 389 (36.8%). The use of the peer reviewed journal as the main communication channel is consistent with the results of previous bibliometric studies in nuclear science and technology (Kademi et al., 2006; 2007). The next highest count was academic theses (270 or 25.5%). The impressive figure recorded for theses in Ghana was not surprising because in Ghana this is

mandatory for all MPhil. and PhD. students of nuclear science and technology before graduation. Moreover, there has been an increase in the number of thesis records in the INIS Database in recent years since the establishment of the Graduate School of Nuclear and Allied Sciences in Ghana and the School's present status as the International Atomic Energy Agency's (IAEA) African Regional Centre for professional and higher education in nuclear science and technology. This was followed by Scientific and Technical Reports 185 (17.5%); Miscellaneous items (mainly non-commercially available unbound conference papers, collection of abstracts, pamphlets, brochures) 139 (12.58%) and Books and published conference proceedings 74 (7%).



5.4.1 Country of Publication of Journal Articles

The rest of the analysis was limited to journal articles because of their scientific value. Table 4 presents the distribution of the journal articles by country of publication. The 389 journal articles were found to be scattered in 74 journal titles, originating from 16 countries. The country with the highest number of journal articles was Ghana with 187 articles, spread over thirteen journals; followed by the United Kingdom with 113 articles, spread over thirty one journals. Hungary followed with 39 articles, all in one journal; Netherlands with 18 articles, spread over seven journals and the United States of America with 9 articles, spread over 7 journals; India with 5 articles in two journals; Japan with 2 articles in two journals; Pakistan with 2 articles in one journal; and Australia, China, Egypt, France, Ireland, Italy and Poland with a count of 1 article each per journal. Surprisingly, apart from Ghana, no other African country, except Egypt, had a share of the journal articles, which confirms the poor communication between and among African scientists at the regional level as observed by Teferra (2003).

Table 4: Distribution of Journal Articles by Country of Publication

Country of Publication	No. of Articles	No. of Journals	%	Average
Ghana	187	13	48.07	14.38
United Kingdom	113	31	29.04	3.64
Hungary	39	1	10.05	39
Netherlands	18	7	4.62	2.57
United States	9	7	2.31	1.28
Germany	7	3	1.79	2.3
India	5	2	1.28	2.5
Japan	2	2	0.51	1
Pakistan	2	1	0.51	2
Australia	1	1	0.25	1
China	1	1	0.25	1
Egypt	1	1	0.25	1
France	1	1	0.25	1
Ireland	1	1	0.25	1
Italy	1	1	0.25	1
Poland	1	1	0.25	1
Total	389	74	100	

Further analysis of the journal articles revealed that, majority 202 (52%) of the articles were published in foreign journals, compared to 187 (48%) that were published in local journals, though the difference was just 4%. Lancaster (1982) posits that, majority of scientists in developing countries opt to publish in foreign journals rather than in their local journals for prestige and recognition. Another possible explanation for the slight edge of local journals over foreign journals in this instance can be attributed to the irregular publication frequency of local journals compared to the foreign journals. Moreover most of the local journals are not listed in the major international indexing and abstracting services, hence the preference to publish in high journals to ensure visibility. It will be worthwhile investigating the reasons for the choice of journals.

5.4.2 Key Journals used to Publish Research Results

The study also attempted to identify the Key journals that the scientists preferred to publish in. This was deemed necessary because identifying the top journals within a discipline enables the scientists decide on where to publish their research results and also keep up with the literature in their research areas. A list of core journals also becomes handy during library collection development.

Presented in Table 5 is the rank list of journal titles (abbreviated) and the countries of publication. A greater number of the articles were published in the *Journal of Applied Science and Technology* (55 articles); followed by *Journal of Radioanalytical and Nuclear Chemistry* with 39 articles; *Journal of the Ghana Science Association* with 38 articles; *Radiation Protection Dosimetry* with 26 articles, *Journal of the Kumasi University of Science and Technology* with 22 articles; *West African Journal of Applied Ecology* with 21 articles; *Ghana Journal of Science* with 14 articles; *Applied Radiation and Isotopes* with 14 articles, *Annals of Nuclear Energy*; and the *IOP Conference Series (Earth and Environmental Science)* and *Radiation Physics and Chemistry* with 11 articles each. Out of the 11 journals identified as key, 5 are published in Ghana, 5 originated from the United Kingdom, and 1 from Hungary. The key journals covered approximately 67% of the total number of articles.

Table 5: Rank List of Journals

Rank	Journal	Country	No. of articles	%	Rank	Journal	Country	No. of articles	%
1	J Applied Sci Technol	Ghana	55	14.13	13	Cyst Res Technol	Germany	4	1.02
2	J Radioal Nuc Chem	Hungary	39	10.02	13	Ghana J Chem	Ghana	4	1.02
3	J Ghana Sci Assoc	Ghana	38	9.79	13	Ghana Med J	Ghana	4	1.02
4	Radiat Prot Dosim	UK	26	6.68	13	Rad Protect environ	India	4	1.02
5	J Kumasi U Sci Technol	Ghana	22	5.65	14	Ghana Min J	Ghana	3	0.77
6	W Afr J Appl Ecol	Ghana	21	5.39	14	J MedBiomedical Sci	Ghana	3	0.77
7	Ghana J Sci	Ghana	14	3.59	14	Nucl Instrum Methods	Netherlands	3	0.77
7	Int J Appl Radiat Is	UK	14	3.59	15	Kristall und Technik	Germany	2	0.51
8	Ann Nucl Energy	UK	11	2.82	15	Sci Total Environ	Netherlands	2	0.51
8	IOP C Ser Earth Env	UK	11	2.82	15	Sci Vision	Pakistan	2	0.51
8	Radiat Phys Chem	UK	11	2.82	15	Environ Pollut	UK	2	0.51

9	ERG B	Ghana	9	2.31	15	J Geophys Eng	UK	2	0.51
9	Nucl Eng Des	Netherlands	9	2.31	15	J of Radiol Prot	UK	2	0.51
10	Agr Food Sci J Ghana	Ghana	7	1.79	15	Renew Energ	UK	2	0.51
10	Energ Policy	UK	7	1.79	15	Int J Radiat Oncol\	USA	2	0.51
11	Ghana J Agr Sci	Ghana	6	1.54	15	Int J Theor Phys	USA	2	0.51
12	Mater Design	United Kingdom	5	1.28	16	Other Journals with one (1) Article	Various	41	10.25

5.5 What Is the Authorship Trend in Nuclear Science and Technology?

Table 6 shows the distribution of the journal records by number of authors per article. The total number of authors was 1,394 with an average of about 3.6 articles per author. The number of authors per paper ranged from 1 author to 21 authors. Three-authored papers formed the majority, with 85 (21.85%) articles; followed by single authored papers with 79 (20.3%), double authors with 67 (17.2) articles; 4 authors with 58 articles (14.91%) articles, 5 authors with 40 (10.20%) articles; 7 authors with 19 articles (4.88%); 8 authors with 8 articles and 9 authors with 6 articles. There were 2 articles with 19 and 21 authors each.

Table 6: Distribution of journal articles by number of authors

<i>No. of authors</i>	<i>No. of articles</i>	<i>% of journal articles</i>
1	79	20.3
2	67	17.2
3	85	21.85
4	58	14.91
5	40	10.28
6	16	4.11
7	19	4.88
8	8	2.05
9	6	1.54
10	1	0.25
11	1	0.25
12	5	1.28
13	2	0.51
19	1	0.25
21	1	0.25
Total	389	100

Aggregating the double and multi-authored papers against the single authored papers, double (17%) authored and multi-authored (63%) papers accounted for 80% of the total, while the single authored papers accounted for only 20%. This reflects the interdisciplinary nature of the field. It is also an indication of teamwork and collaboration among the nuclear scientists, which is well documented (Kademi et al., 2006; Sagar, Kademani and Kumar, 2009; Girap et al., 2011; Davarpanah, 2012); etc.

6. Conclusions

This quantitative study sought to investigate the research focus and trends in nuclear science and technology in Ghana based on publications listed in the INIS Bibliographic Database. About 1,057 publications, mainly journal articles, reports, theses, books, and conference papers covering the period 1964 to 2014, were retrieved and analysed.

According to the results, majority of the nuclear science and technology records in the INIS Database were published in Ghana (598 or 56.57% against 459 or 43.43% published outside Ghana).

A significant finding of the study was the increasing trend in the number of publications over the years with the most productive year being 2012 with a count of 98 (9.2%) publications. It was also observed that, one-third (33.58) of the documents were published in recent years from 2010 to 2014.

The study further revealed that, Applied Life Sciences comprising plant cultivation & breeding, pest & disease control, food protection, preservation, human nutrition and Animal husbandry was the main focus of research with 228 (21.5%) publications; followed by Chemistry (135 or 12.77%); Environmental Sciences (125 or 11.8%), Radiation Protection and Dosimetry (111 or 10.5) and Nuclear Reactors (99 or 9.6%). The least researched area was Safeguards and Physical Protection.

The study also revealed that nuclear science and technology researchers in Ghana preferred to publish in peer reviewed science and technology journals with a count of 389 (36.8%) as opposed to other communication channels such as reports and books. The bulk of the journal articles were published in Ghana (187 representing 48.02%) and the United Kingdom (113, representing 29.04%).

It was also observed that majority of the nuclear scientists preferred to publish in foreign journals (202 articles or 52%) against local journals (187 or 48%) though the difference was not all that significant.

The Key journals identified in this study were *Journal of Applied Science and Technology*; *Journal of Radioanalytical and Nuclear Chemistry*; *Journal of the Ghana Science Association*; *Radiation Protection Dosimetry*; *Journal of the Kumasi University of Science and Technology*; *West African Journal of Applied Ecology*; *Ghana Journal of Science*; *Applied Radiation and Isotopes*; *Annals of Nuclear Energy*, *IOP Conference Series (Earth and Environmental Science)* and *Radiation Physics and Chemistry*.

A large proportion of the papers was multi-authored (202 or 80%), with three authored papers dominating. It will be useful to further probe the degree of collaboration and the types of collaborative networks that exist within and outside the Country.

In this study, the quantitative bibliometric technique, based on simple document counting was used to assess various features of the publications. Moreover, the source of data was limited to the INIS Bibliographic Database. In future, it will be worthwhile to conduct a qualitative evaluation of the nuclear science and technology publications to determine their impact using citation analyses from other scientific data sources, apart from INIS.

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