A GLOBAL ASSESSMENT OF NANOTECHNOLOGY ACTIVITIES PART 1: A LOOK AT PUBLICATIONS

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Abstract

A study on the state of nanotechnology in the world on the basis of a Scientometric indicator was done. The volume and distribution of scientific publications is reported in this paper. The analysis was carried out by using data published from a database produced by Thomson Reuters–The Web of Science ™. The period under review is 1995 to 2011. The analysis shows that a total of 308,586 nanotechnology scientific publications were recorded for the period under consideration. Africa, North America, South America, Europe, Asia, Australia and Eurasia contributed 0.58%, 23.36%, 1.37%, 25.32%, 45.81%, 1.34% and 2.21% of the world's total number of scientific publications respectively. The seven most-prolific areas of nanotechnology scientific publications globally were: Nanoparticles and Quantum Dots (25%), Nanofabrication and Processing (20%), Nanotubes and Nanowires (19%), Quantum Devices (6%), Nanocatalyst (6%), Photovoltaic and Solar Cells (3%) as well as Functionalization of Nanotubes, Nanowires and Nanoparticles (2 %).

Keywords*: Nanotechnology, Publications, Nanoparticles, Quantum Dots, Nanofabrication*.

1. Introduction

1.1 Nanotechnology

The National Nanotechnology Initiative has defined nanotechnology as the manipulation of matter with at least one of the dimensions sized from one to hundred nanometres [1]. The definition includes all types of research and technologies that deal with the special properties of matter that exists below the given size threshold.

The application of nanotechnology has been tipped as one of the technological solutions that can help in addressing some of the key problems affecting energy, water, food, environment and disease [2]. The benefitsof nanotechnology are numerous and applies to both developed and developing countries [3].

1.2 Scientometry

Scientometry is the study of measuring and analysing science, technology and innovation. It is also defined as the qualitative study of science, communication in science and science policy [4]. Major research issues border on the measurement of the impact of journals and institutes, understanding of scientific citations, mapping scientific fields and the production of indicators for use in policy and management contexts.

The basis of modern Scientometrics was formed from the works of Derek J. de Solla Price [5-7] and Eugene Garfield culminating in a full-fledged research work [8]. Eugene Garfield formulated the Science Citation Index [8-9] which started as an idea of an index to improve information retrieval sometime in the 1960s. It was soon recognized as a novel instrument in the empirical study of the sciences [7, 10].

In analysing scientific works, Scientometric indicators are used. They are simply the tools utilized in the analysis of scientific publications. They are broadly classified into three, namely:

- Input indicators: these are the easiest to collect. They provide information on the development of a

technology in a given region, country or in the world. They are further classified into human resources, financial resources and infrastructure.

- Output Indicators: these provide information on the trajectories of a technology and on key areas of innovation. They are further classified into prizes, bibliometric indicators and patent indicators.
- Efficiency Indicators: these are classified based on various input/output relations or inter and intra-institutional relationships.

1.3 Some Scientometric Studies on Nanotechnology

Hullmann conducted a research on the topic; economic development of nanotechnology-an indicator based analysis [11]. Available data was analyzed on the state-of-the-art nanotechnology markets and market projections on jobs, on companies and on other organizations active in nanotechnology, on public and on private funding. The study also tried to discover the economic and social contributions of nanotechnology in line with the goals of the European Union. From the study, the largest shares of the market for nanotechnology products were attributed to Nano devices and Nano biotechnology accruing 420 and 415 million US dollars respectively. On the other hand, materials and tools were found to play minor roles with about 145 and 50 million US dollars respectively. A more reliable data source, however, revealed that Nano tools actually play the most important role in the world market although they recorded the smallest growth rates. The study also revealed that private investors were lagging behind their public counterparts in Europe as regards funding unlike in countries such as the United States and Japan where the funding is relatively balanced.

Marx and Andreas conducted a Scientometric study of carbon Nanotubes sourcing the data necessary for the research from the Science Citation Index (SCI) including the Conference Proceedings Citation Index, Science (CPCI-S) under the Web of Science (WOS) [12]. Their study revealed that as at the time of research, there were a total of 57,128 publications related to Nanotubes. The productivity of the output increased by a factor of 200 which was far above the overall growth of scientific literature in the same period, according to the study. Authors considered most productive in the field, according to the WOS-analyze function were listed most of which were from China, Japan and the United States.

Some other Nano-related Scientometric studies have been reported in [13-18] for different countries and at different periods.

The objective of this paper is to assess the Nano related activities globally, by carrying out a Scientometric analysis of scientific papers published in peer review journals. The outcome of this work has potential benefits for identifying emerging areas of scientific research, examining the development of research over time and for decision makers.

2. Methodology

The data used for this study were extracted from data published by Thomson Reuters [15]. The Web of Science™ is a database made by Thomson Reuters. It is a repository for published papers from over 12,500 peer-reviewed, high impact factor scientific journals [19].

The scientific literature collections created for the study were produced using technology search strings for each of the 44 sub-technology areas (see Table 1) of relevant interest.

3. Results and Discussions

3.1 Nanotechnology Scientific Publications in various Continents by Source.

Results obtained from the analysis indicate that the total number of scientific papers published between 1995 and 2011 was 308,586. The total number of publications in Africa, North America, South America, Europe, Asia, Australia and Eurasia were 1,779, 72,076, 4,243, 78,146, 141,374, 4,145 and 6,823 respectively (see Figure 1). Comparing the figures for each continent against the world's total, the average percentage publication would be approximately 0.58%, 23.36%, 1.37%, 25.32%, 45.81%, 1.34% and 2.21% for the respective continents. A closer

look at the amounts of nanotechnology scientific papers in the world (see Figure 1)

Table 1: Sub-Technology Categories of Interest by Source [Thomson Reuters, 2014a].

MEMS Sensors	Nanofabrication & Processing	Nanotubes & Nanowires	New Material & Nanostructure Modelling
MEMS Actuators	Displays	Material enhancement using Nanotubes, Nanowires & Nanoparticles	Photovoltaic & Solar Cells
RF MEMS	Nano Sensors	Nanoparticles & Quantum Dots	Photonic Crystals
Drug Delivery	Functionalization of Nanotubes, Nanowires & Nanoparticles	Textile: Fire/Water Resistant	Spintronic
Imaging	Semiconductor Laser & Devices	Adhesives	ASIC
Bio-MEMS Devices	Quantum Devices	Energy Harvesting	Radiation Protection
Laser & Detection	Nanocatalyst	Fuel Cells	Nano filtration
LEDs	Fuel Additives	High Performance Batteries	Composite Materials
Integrated Optics	Fuel Extraction	Lubrication	Thermal Insulation
Optical Components	Anti-corrosion	Water purification, Desalination & Decontamination	Nano devices & Modeling
Optical Sensors	Self-cleaning	Water Quality Monitoring	Nano toxicity & Safety

shows that nanotechnology-related research was concentrated in three continents; Asia which is predominant, Europe and North America. These three continents alone produced approximately 94.4% of the world's total nanotechnology publications. The four other continents had relatively low volumes of scientific publications with the highest of them being Eurasia, followed by South America, then Australia and Africa.

In order to check the "publication density" in each continent – this is the ratio of the total volumes of publications from a continent divided by the total number of countries representing the continent. Figure 2 gives an indication that the publication density was highest in North America. This value is ~24,025 publications per participating country during the period. This is followed by those of Eurasia (6,823 publications per country), Asia (~3,720 publications per country), Australia (~2,072 publications per country), Europe (~1,817 publications per country), South America (~282 publications per country) and Africa (~77 publications per country).Even though Asia was clearly seen in Figure 1 to dominate in terms of total number of nanotechnology scientific publications, however when compared against the number of participating countries in Fig. 2, North America took the lead since the number of participating countries is just three. Eurasia followed after North America and Asia came third. This is not surprising since Eurasia is represented by only one country.

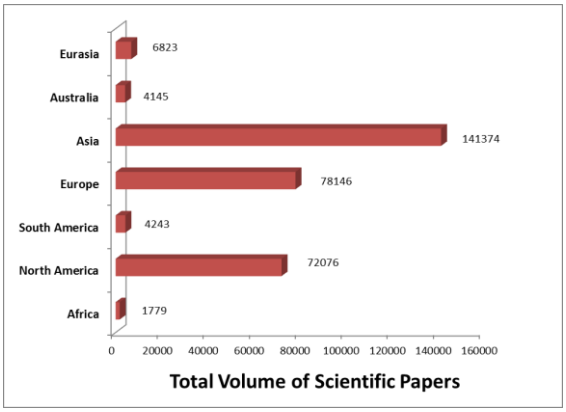

Figure 1: Sources of Nanotechnology Scientific Papers from Different Continents.

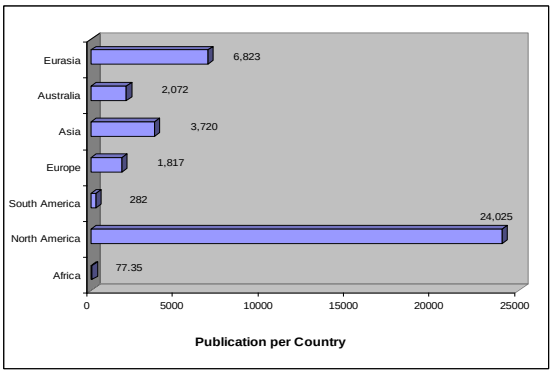

Figure 2: Nanotechnology "Publication Density" in each Continent (1995-2011).

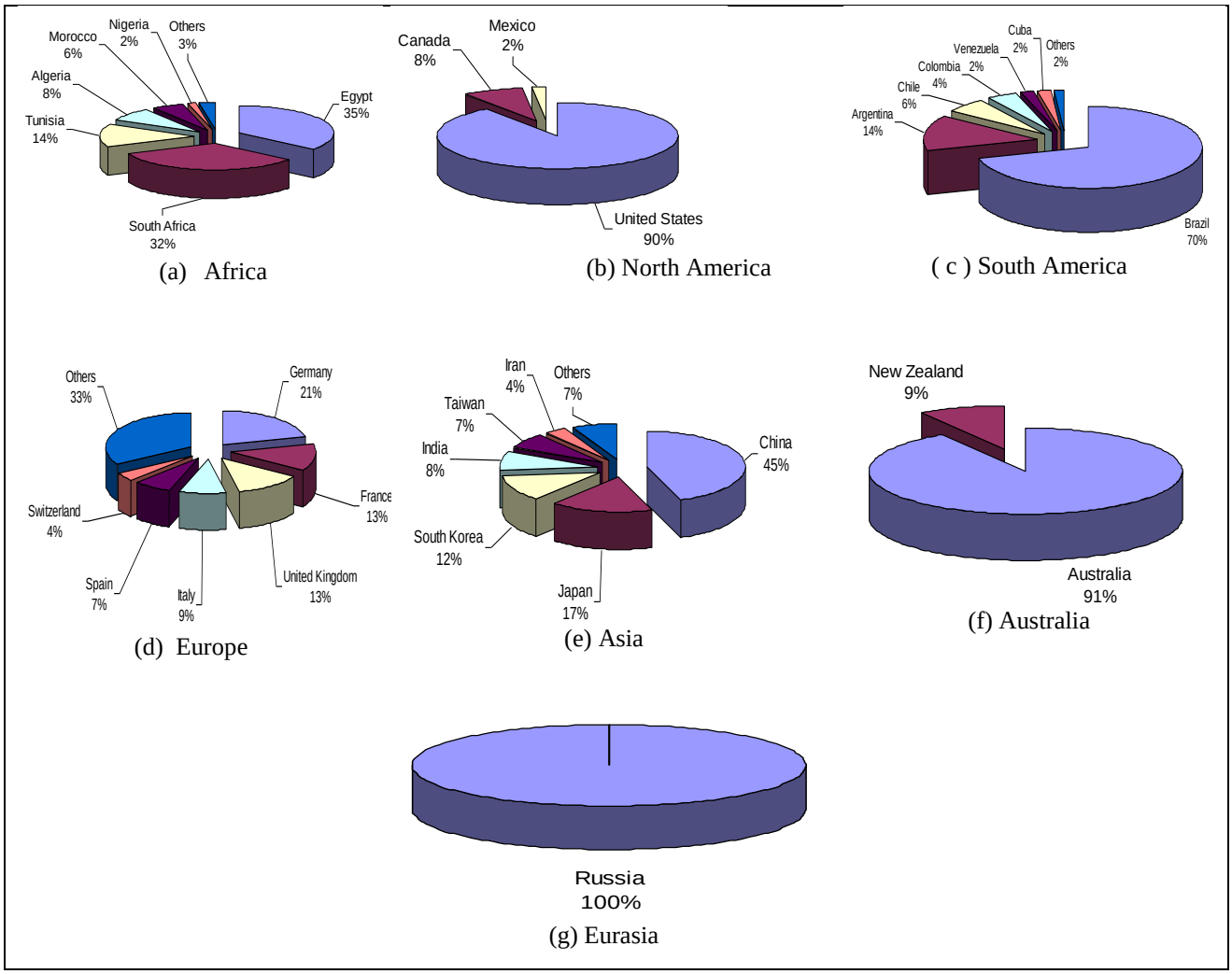

Figure 3: Major Contributors to Nanotechnology Scientific Publications in various Continents(1995-2011).

The major contributors in each continent are presented in Figure 3(a)-(g). In Africa; Egypt, South Africa and Tunisia were the top three countries with a combined output of 81% of the total continental publications. In North America, the United States was the major contributor with an output of 90% of the total continental publications. In South America; Brazil was had the highest contribution with an output of 70% of the total continental publications. In Europe; Germany, France, the United Kingdom, Italy and Spain were the major contributors with a combined output of 77% of the total continental output of publications. In Asia; China, Japan, South Korea, India and Taiwan were the major contributors with a combined output of 82% of the total continental publications. In Australia, Australia dominated by contributing 91% of the entire continental publications.

3.2Trends in Nanotechnology Publications in various Continents:

The annual trend for nanotechnology scientific publications over the period; 1995-2011 is depicted in Figure 4. Generally, it is observed that Asia experienced the highest rate of annual growth followed by Europe and North America, Eurasia, Australia, South America and Africa. Growth in the annual volumes of nanotechnology scientific publications started between 1997 and 1998 for Europe, Asia and North America with Europe leading which left both Asia and North America roughly at par with each other. Asia sustained a higher rate of growth than North America between 1999 and 2000 and by 2001, its volume of scientific publications had slightly surpassed that of Europe. This growth rate was consistent and rather incremental in

nature with the highest growth rate recorded between 2009 and 2010. The European and North American counterparts generally did not enjoy such annual growth rates as did the Asian. Europe was able to fairly maintain consistency in their growth rate until the period between 2003 and 2004 when North America caught up with it and slightly surpassed over the period of 2004 and 2006. Again, between 2006 and 2007 both continents managed to keep abreast each other. However, Europe regained its speed over North America only slightly between 2007 and 2009. The continent was able to sustain a little increase in their growth over North America throughout the rest of the period but had an almost linear growth between 2010 and 2011.

North America, on the other hand suffered a little set-back hence falling just a little below the Europeans in terms of volume of nanotechnology scientific papers. Also to be noted is the slight decline in their growth rate between 2010 and 2011.For the Eurasian countries, there was no significant growth in the volume of nanotechnology-related science papers within the same period. A very close observation of Figure 4 reveals that Eurasia began producing a few hundreds of publications by 2000. This was roughly maintained although with slight progressive increases before a slight decrease set in between 2010 and 2011. Almost the same trend could be projected for Australia only that their volume of nanotechnology scientific publications were less than that of Eurasia by a small amount for the respective periods. Again, Australia was able to produce a few hundreds of publications by 2006, unlike Eurasia. It was also able to maintain a growth rate although outside the period under consideration only that the proportion in which the growth increased was little. South America followed down the line with a consistent annual growth rate in the volume of scientific publications until 2011 when there was a slight decline. Africa came last on the scale. There were fluctuations in the rate of growth from 1995 to 2003. Consistent growth rate started in 2003. This consistency was maintained till the end of the period under review.

3.3 Nanotechnology Scientific Papers by Research Area:

The seven most prolific areas of nanotechnology scientific papers globally were: Nanoparticles and Quantum Dots(25%);Nanofabrication and Processing (20%); Nanotubes and Nanowires (19%); Quantum Devices (6%); Nanocatalyst(6%); Photovoltaic and Solar Cells (3%); and Functionalization of Nanotubes, Nanowires and Nanoparticles (2%). Refer to Figure 5.

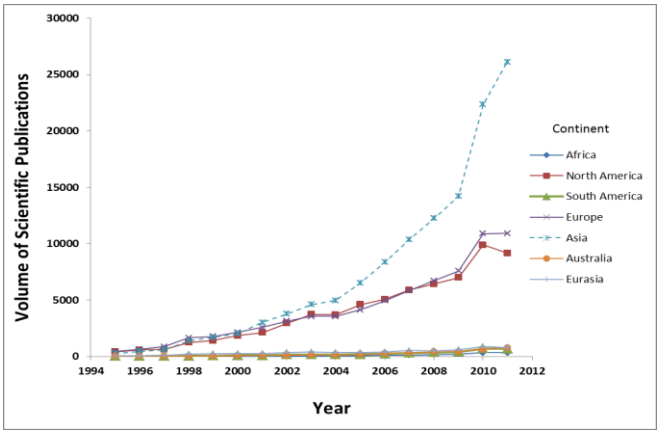

Figure 4: Annual Nanotechnology Scientific Paper Trend in the World (1995-2011).

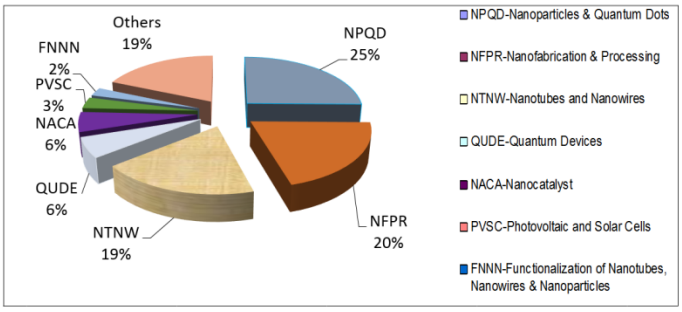

Figure 5: Seven Most-Prolific Areas of Nanotechnology Scientific Papers (1995-2011).

At the continental level, Figure 6(a)-(g) shows what happened in various continents as far as the top ten prolific areas of nanotechnology papers is concerned. Most continents such as North America, South America, Europe, Australia and Eurasia had the highest volume of research papers in Nanoparticles and Quantum Dots (NPQD). This explains the reason why the global outlook in Figure 5 puts NPQD as the highest area of publication. However, Africa and Asia were exceptions – not having Nanofabrication and Processing (NAPR) as the area with the highest volume of nanotechnology scientific publications. Nanotubes and Nanowires as well as Nanofabrication and Processing struggle for the second most-prolific area of nanotechnology

scientific publications in most continents. It must be noted that Energy harvesting (ENHA) emerged as joint highest research area.

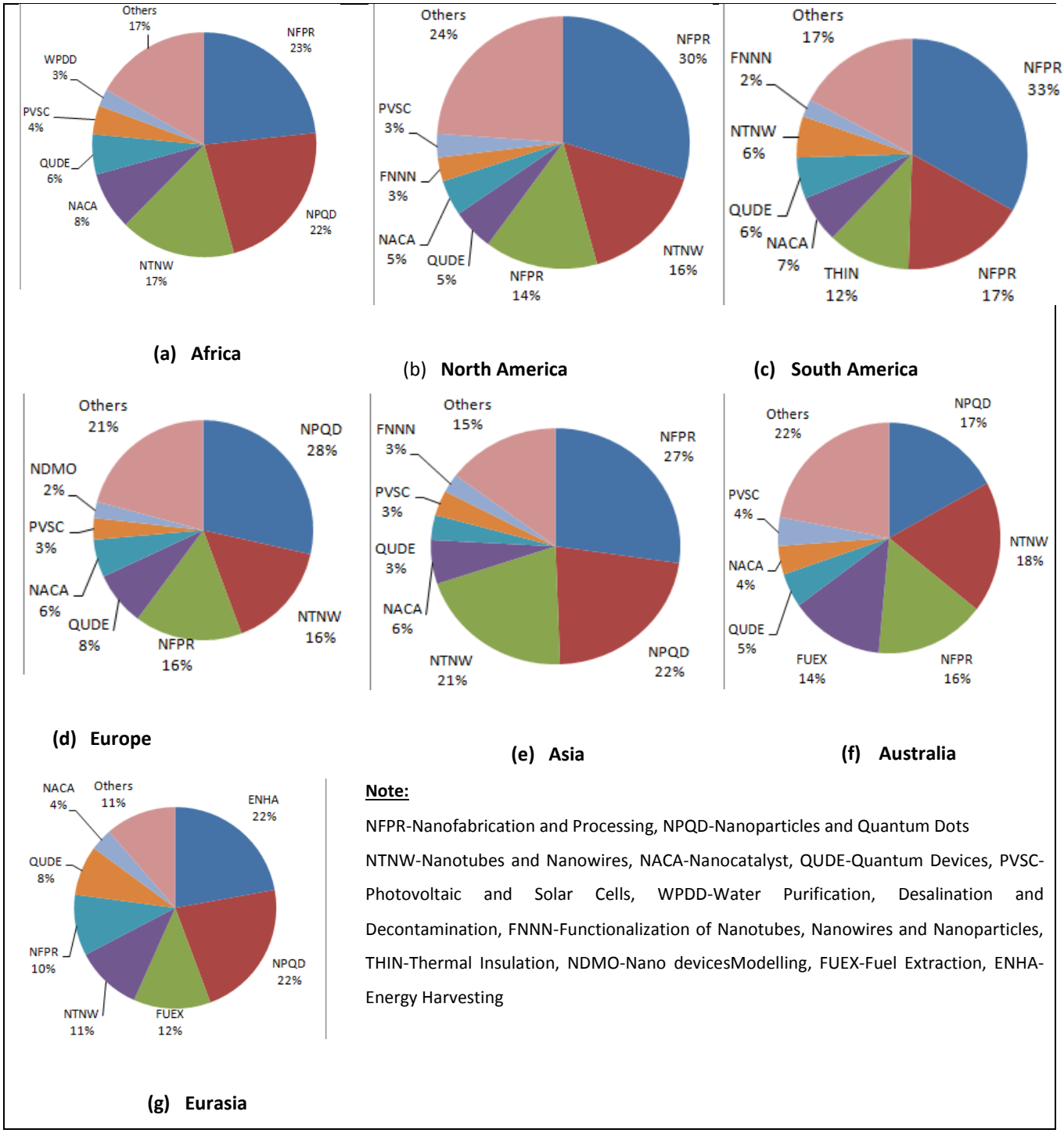

Figure 6:Seven Most-Prolific Areas of Nanotechnology Scientific Publications at the Continental Level (1995-2011).

4. Conclusions

Results from the study indicate that a total of 125 countries participated in nanotechnology-related scientific publications globally between the periods under review. 23 countries were from Africa, 3 from North America, 15 from South America, 43 from Europe, 38 from Asia, 2 from Australia and 1 from Eurasia.

The total volume of nanotechnology scientific publications was 308,586 out of which 0.58%, 23.36%, 1.37%, 25.3%, 45.81%, 1.34%, and 2.21% came from Africa,North America, South America, Europe, Asia, Australia and Eurasia respectively.

The top seven most-published areas of nanotechnology scientific literature were: Nanoparticles and Quantum Dots (25 %), Nanofabrication and Processing (20%), Nanotubes and Nanowires (19%), Quantum Devices (6 %), Nanocatalyst (6 %), Photovoltaic and Solar Cells (3%) as well as Functionalization of Nanotubes, Nanowires and Nanoparticles (2%).

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Acronyms

BMDE Bio-MEMS Devices
COMA Composite Material
ENHA Energy Harvesting
FNNN Functionalization of Nanotubes, Nanowires and Nanoparticles
FUAD Fuel Additives
FUEX Fuel Extraction
HPBA High Performance Battery
IMAG Imaging
NFPR Nanofabrication and Processing
NDMO Nanodevices Modeling
NTSF Nanotoxicity and Safety
NPQD Nanoparticles and Quantum Dots
NTNW Nanotubes and Nanowires
NACA Nanocatalyst
NASN Nansensors
NAFL Nanofiltration
PHCR Photonic Crystals
PVSC Photovoltaic and Solar Cells
QUDE Quantum Devices
THIN Thermal Insulation
WPDD Water Purification, Desalination and Decontamination