Journal of Scientific Research and Studies Vol. 2(8), pp. 187-194, October, 2015
ISSN 2375-8791

http://www.modernrespub.org/jsrs/index.htm

Review

Nanotechnology, energy and nanomedicine: a survey on scientific communications

Ana C. Costa da Silva and Nelida L. del Mastro*

Instituto de Pesquisas Energéticas e Nucleares (IPEN), University of São Paulo, São Paulo, SP, Brazil.

*Corresponding author. E-mail: nlmastro@ipen.br

Accepted 20 October, 2015

Nanotechnology is a broad spectrum of products and processes spanning mainly human health and energy, but also agriculture, the environment and many other industries and classifications. Different attempts are made for measuring activity and investments to help inform strategy and policy decision making on the scientific, economic, health, environmental and social impacts of nanotechnology. For that reason, an overview of the current state of research communications on specific areas in connection to nanotechnology is necessary. In the present work, a survey was performed considering just the published scientific papers using online databases like Web of Science and accessing using different related terms and combinations. Data were collected since the first register from the 1970s until May 2015. The relationship between nanotechnology applied to energy transformations was established. In particular, the relationship between nuclear energy and nanotechnology is quite limited now, but it is expected to increase in the short term. Independently of the term and the combination of terms employed, a tendency is showed: nanotechnology exhibits almost exponential growth and this interdisciplinary technology can be considered as a new industrial revolution.

Key words: Nanotechnology, biomedicine, energy sources.

INTRODUCTION

Technological advances are linked to the discovery or development of materials with novel features. A definition of nanotechnology must include the characteristics of size, control, function and performance covering three aspects: a) The study and manipulation of matter on a nanometer length scale; b) The ability to control matter on a nanometer length scale for the construction of new materials with novel properties (physical, chemical, biological) and/or functions (e.g. quantum effects); c) The distinction between naturally occurring nanoparticles (ionic sprays); by-products (diesel emissions); and purposely engineered materials (carbon nanotubes, quantum dots). The most accepted definition (Bawa et al., 2008) described nanotechnology as the design, characterization, production and application of structures, controlled manipulation of size and shape at the nanometer scale, which produce structures, devices and systems with at least one feature or new/higher property. The so-called nanomaterials, nanoparticles and nanocomposites show new physical and chemical properties, which combine the classical and the quantum world and emerge in surprising and unusual way in science and everyday life.

Some of the already available applications of nanotechnology on energy sources are:

1. Photovoltaics: Nano-optimized cells (polymeric, dye, quantum dot, thin film, multiple junction), antireflective coatings.
2. Wind Energy: Nano-composites for lighter and stronger rotor blades, wear and corrosion protection nano-coatings for bearings and power trains, etc.
3. Geothermal: Nano-coatings and -composites for wear resistant drilling equipment.
4. Hydro-/Tidal power: Nano- coatings for corrosion protection.
5. Biomass energy: Yield optimization by nano-based precision farming (nanosensors, controlled release and

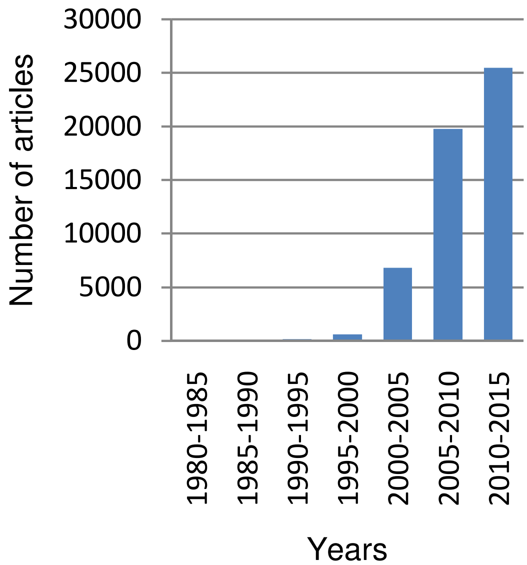

Figure 1. Number of articles found in the Web of Science per year of publication using the word *nanotechnology* (until May 2015).

storage of pesticides and nutrients).

On the other hand, under the title of biomedicine is included all possible applications on diagnosis and therapeutics, besides connected researches.

Products that are developed through nanotechnology are divided into four different generations (Renn and Roco, 2006). The first are products manufactured until approximately 2000, include nanostructured coatings, nanoparticle dispersion, nano surfaces standard and bulk materials (raw materials), as nanostructured metals, polymers and ceramics; the materials of this generation have stationary structures. The second generation is characterized by active nanostructures such as, for example, new transistors, target drugs and chemicals manufactured from 2000 to 2005. The third generation begun in 2005 characterized by the use of various synthesis and assembly techniques such as robotics, biofabrication and multiscale associated with nanosystems based on quantum mechanics. The fourth generation is described for the future commencing between 2015 and 2020 involving heterogeneous molecular nanosystems where each molecule in a nanosystem has a specific structure with a different role.

Nanoscience and nanotechnology are new frontiers of this century. Some applications like in nuclear technology, renewable energy or agriculture are relatively recent compared with their use in drug delivery, pharmaceuticals and medical practice (Stylios et al., 2005; Sozer and Kokini, 2009; Bang and Jeong, 2011; Zang, 2011).

Almost twenty years ago, Marien (1996) described the impacts and issues on new communications technology. Different attempts were made for measuring activity and investments to help inform strategy and policy decision-making on the scientific, economic, health, environmental and social impacts of nanotechnology.

A huge amount of papers were published since the use of the word nanotechnology started to be employed, both from local or international sources (Ozin and Arsenault, 2005; Duran et al., 2006; De et al., 2008; Cortie et al., 2013; Mao et al., 2013; Patricio et al., 2013; Plentz and Fazzio, 2013; Brasil, 2014; Serrano et al., 2014). Then, a survey collecting such sort of information appeared in databases is possible to be performed.

Usually a practical survey of this kind is conducted by means of questionnaires sent to different firms on emerging technology or together with surveys on biotechnology. In all the cases, any survey is limited, and can be considered as an approach to the actual state of the art. In the present work, a survey was performed considering just the published scientific papers using online databases.

METHODOLOGY

A survey on nanotechnology was performed considering just the published scientific papers using online databases and different related terms and combinations. Databases, generally considered to be “A-level” like Web of Science, were selected for assessment. We believe that this pragmatic approach is defensible as studies appearing in the top journals reflect the enacted best research practices of the field. In order to compile data on human health, the database accessed were, besides Web of Sciences, Medline, PubMed, Scopus and

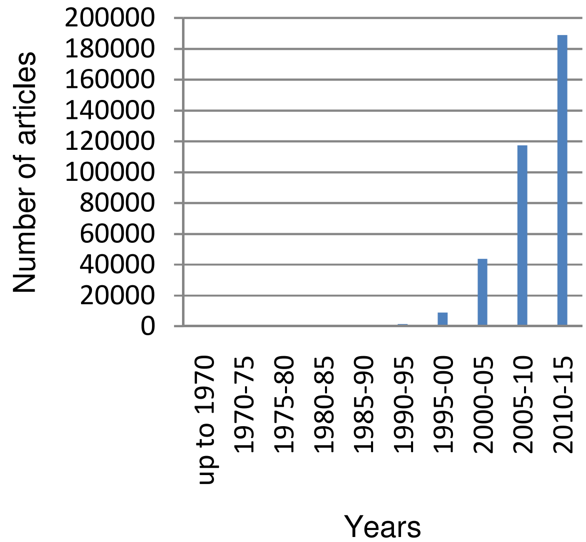

Figure 2. Number of articles found in Web of Science per year of publication using the word *nanoparticle* since 1970 (until May 2015).

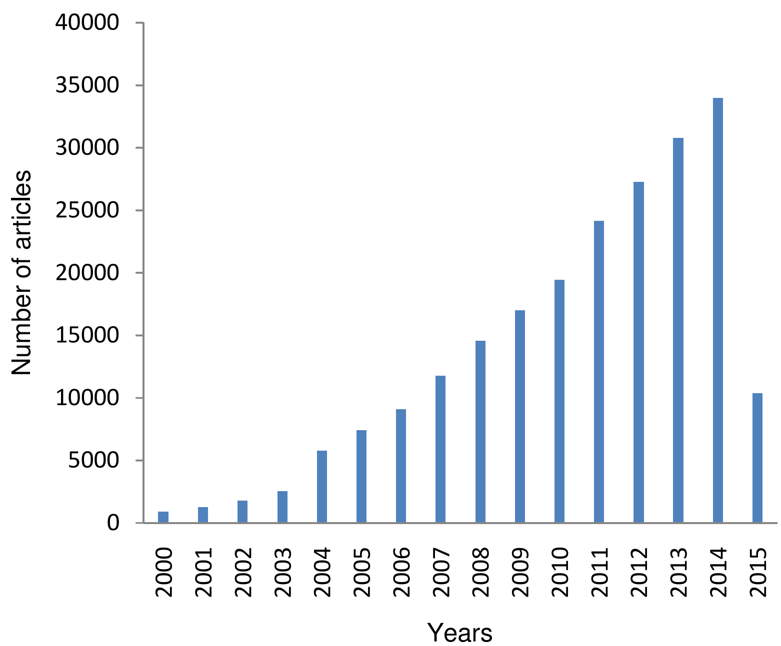

Figure 3. Number of articles found in Web of Science per year of publication using the word *nanoparticle* from 2000 until May 2015.

IAEA/INIS. The International Nuclear Information System (INIS) hosts one of the world's largest collections of published information on the peaceful uses of nuclear science and technology. It offers online access to a unique collection of non-conventional literature. The INIS is operated by the International Atomic Energy Agency (IAEA) in collaboration with over 150 members. Data were collected since the first register on the 1970s until May 2015.

RESULTS

Figures 1, 2 and 3 display the importance of the subjects

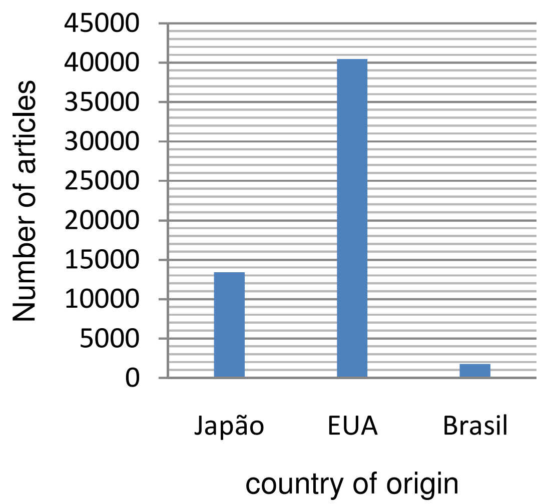

Figure 4. Number of articles found in Web of Science using the word *nanoparticles* with filter by country of origin: Japan, USA and Brazil in the period 2000-May 2015.

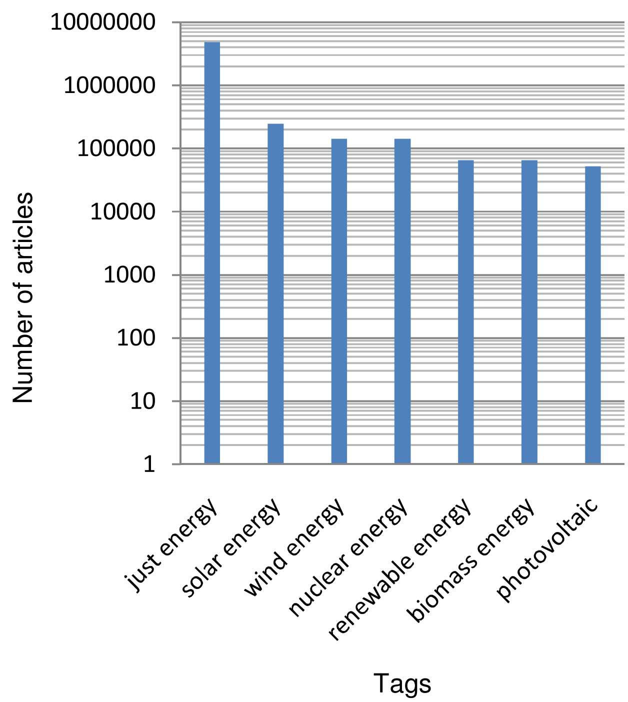

Figure 5. Web of Science survey of the total articles published under the tag *energy, solar energy, wind energy, nuclear energy, renewable energy, biomass energy and photovoltaic energy* using a log scale.

Nanotechnology and *Nanoparticles*, measured by the number of articles found with such tag in the Web of Science since the first article appeared, few decades ago.

Another assessment was carried out based on the number of articles collected in Web of Science with the key word nanoparticles in the search option by country of origin as is shown in Figure 4. In this case, there is a strong difference between USA, Japan and Brazil, where only 1,788 articles appeared from 2000 to May 2015.

Figure 5 presents the total articles published in the

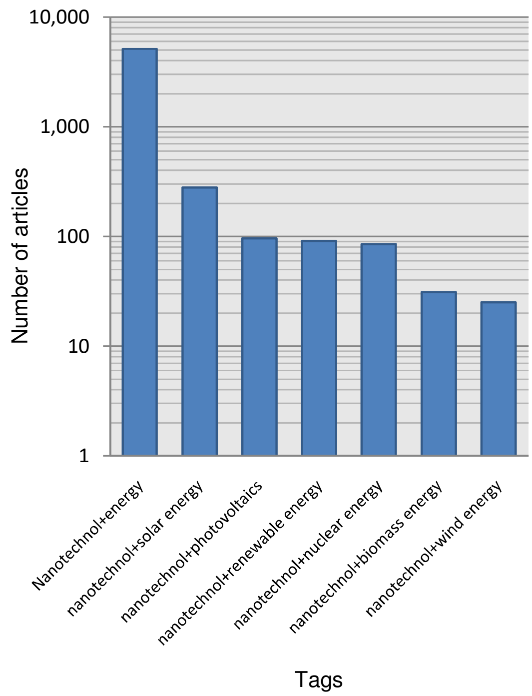

Figure 6. Total number of articles found in Web of Science when the word *nanotechnology* was crossed with *energy, solar energy, photovoltaic energy, renewable energy, nuclear energy, biomass energy and wind energy* using a log scale.

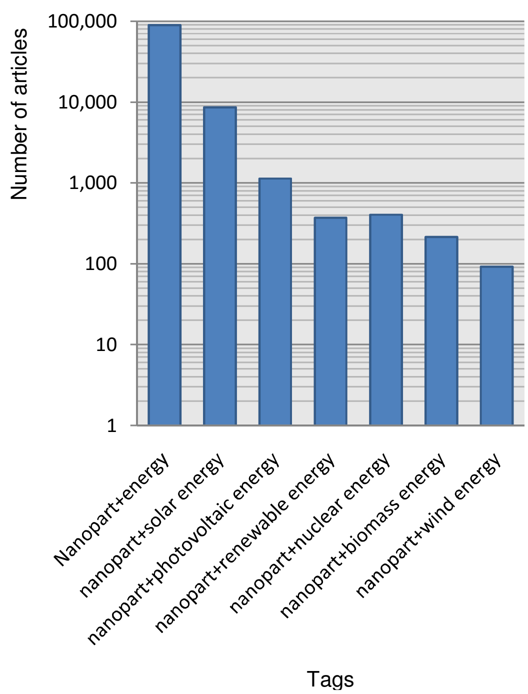

Figure 7. Total number of articles found in Web of Science when the word *nanoparticles* was crossed with *energy, solar energy, photovoltaic energy, renewable energy, nuclear energy, biomass energy and wind energy* using a log scale.

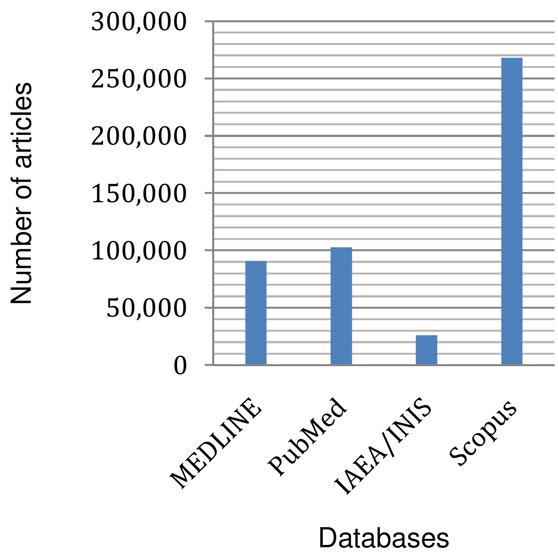

Figure 8. Total number of articles published in 4 databases, Medline, PubMed, Scopus and INIS until May 2015 accessing with the word *nanoparticles*.

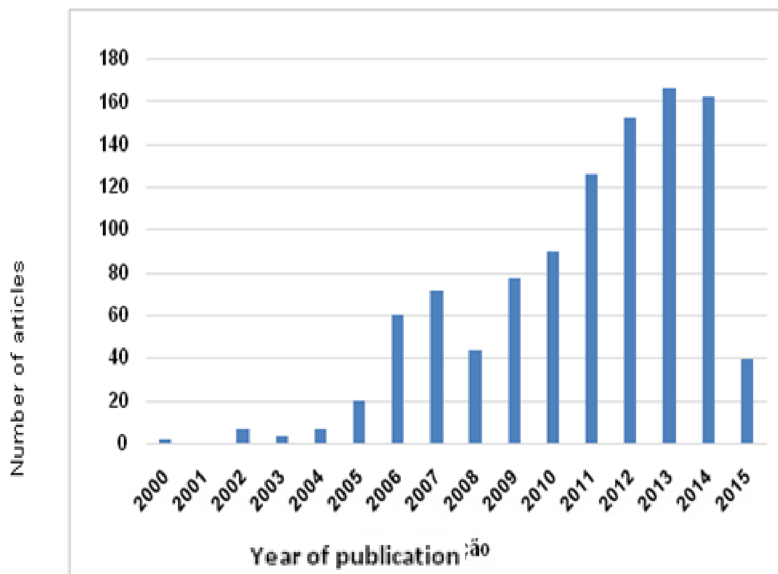

Figure 9. Number of articles found in Web of Science per year of publication accessing the word *nanomedicine* since 2000 (until May 2015).

Web of Science under the tag *energy, solar energy, wind energy, nuclear energy, renewable energy, biomass energy and photovoltaic energy.* Nuclear energy appears as the 3rd in importance, after solar and wind ones.

Figure 6 presents the results collected using the assembly of the word *nanotechnology* crossed with the different energy sources: *energy, wind energy, solar energy, photovoltaic energy, renewable energy, biomass energy and nuclear energy*. It is noticeable that the relative importance of the different kind of energy sources differs considerably when that sort of connections are made.

Figure 7 compiles the similar results of the search crossing the word *Nanoparticles* and the diverse energy sources mentioned above.

In Figure 8 is shown the total number of articles published in 4 databases, Medline, PubMed, Scopus and IAEA/INIS until May 2015, when the access were done

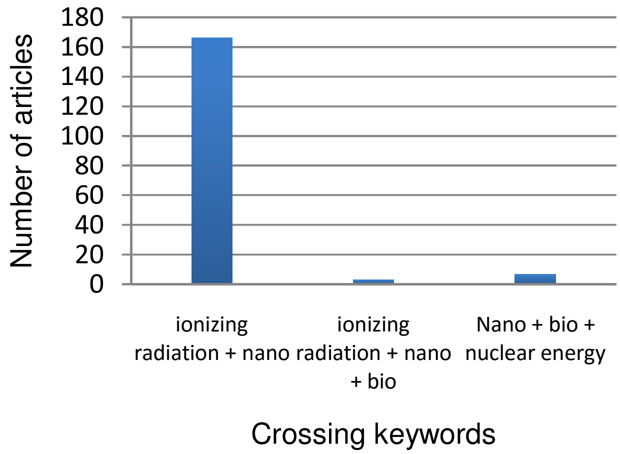

Figure 10. Number of articles in Web of Science crossing keywords as *ionizing radiation + nano, ionizing radiation + bio* and *Nano + Bio + nuclear energy* in article titles in the period 1950-2015.

using the word nanoparticles. As it is possible to see, the relationship between nuclear energy and nanotechnology are quite restricted until now (data collected in INIS) in comparison with other general sources like Scopus, for instance, or MEDLINE dedicated to biomedicine.

In Figure 9, the number of articles found when accessing the term *nanomedicine* is displayed. In Figure 10 is displayed a cross tags survey conducted to show the involvement *of ionizing radiation with nano, ionizing radiation with nano and bio and nano+bio+ nuclear energy.* Nanotechnology involving radiation techniques is poorly widespread until now. Nevertheless, as ionizing radiation has so many applications, further development is expected. Present results show that the intersection of words with the highest index in the proposed period 1950-2015 was *ionizing radiation + nano*.

DISCUSSION

This biblioessay was prepared to make salient the connection between the number of papers on nanotechnology and other areas such as energy, including nuclear energy, and biomedicine. As described in Figures 1, 2 and 3, and also in Figure 9, the number of articles published since the appearance of the first one, few decades ago, is growing extraordinary. In Figure 4 is presented the huge differences in number of publications that can be found when a comparison is made among developed (USA and Japan) and developing country such as Brazil. Figures 5, 6 and 7 displayed the results found when crossing the words nanotechnology or nanoparticle and diverse energy sources. Figure 8 presents the comparison among four databases accessing using the word *nanoparticles*. It is evident that Scopus is the main recipient of that sort of records, as a consequence of the wide range of areas included there. Finally Figure 10 present the result of crossing keywords as *ionizing radiation + nano, ionizing radiation + bio* and *Nano + Bio + nuclear energy* in article titles in the period 1950- May 2015. It is evident the restrict number of publications appeared in those areas so far. Nevertheless, future development can be expected.

Further studies must be done in order to explore in great detail and scope the relationships among them.

CONCLUSION

Present results corroborate the projection of a text mining analysis of the nanotechnology literature performed almost a decade ago (Kostoff et al., 2006). It is expected that public and private support for further nanotechnology development will keep increasing. Nevertheless, the growth and importance that nanotechnology is presenting in all the areas are quite diverse. The relationship between nuclear energy, as well as radiation applications, and nanotechnology are quite limited now, but it is expected to increase in a near future. Independently of the term and the combination of terms employed, a tendency is showed: nanotechnology exhibits almost exponential growth and this interdisciplinary technology can be considered as a new industrial revolution.

REFERENCES

Bang IC, Jeong JH (2011). Nanotechnology for advanced nuclear thermal-hydraulics and safety. Nucl. Eng. Technol. 43(3):217-242.
Bawa BR, Srikumaran M, William JS, Drew H (2008). Nanopharmaceuticals patenting issues and FDA regulatory challenges. Sci. Tech. Lawyer 5(2).
Brasil. ANVISA. (2014). Institutional Diagnosis on Nanotechnology.

(*Diagnóstico Institucional de Nanotecnologia*), http://portal.anvisa.gov.br/wps/wcm/connect/fb117d80436c3cacb1b5 b72a042b41f5/Diagnóstico Institucional+de+Nanotecnologia+-+CIN+2014+-+Dicol.pdf?MOD=AJPERES (*In Portuguese*).
Cortie MB, Nafea EH, Chen H, Valenzuela SM, Ting SS, Sonvico F, Milthorpe B (2013). Nanomedical research in Australia and new Zealand. Nanomedicine 8(12):1999-2006.
De M, Ghosh PS, Rotello VM (2008). Applications of Nanoparticles in Biology. Adv. Mater. 20(22): 4225-4241.
Duran N, Mattoso LHC, Morais PC (2006). Nanotechnology: Introduction, preparation and Caractherization of Nanomaterials and Application Examples (*Nanotecnologia introdução, preparação e caracterização de nanomateriais e exemplos de aplicação*). Artliber Editora Ltda., São Paulo (*In Portuguese*).
Kostoff RN, Stump JA, Johnson D, Murday JS, Lau CGY (2006). The structure and infrastructure of the global nanotechnology literature. J. Nanopart. Res. 8:301-321.
Mao HY, Laurent S, Wei C, Akhavan O, Imani M, Ashkarran AA, Mahmoudi M (2013). Graphene: Promises, Facts, Opportunities, and Challenges in Nanomedicine. Chem. Rev. 113(5):3407-3424.
Marien M (1996). New communications technology: A survey of impacts and issues. Telecomm. Policy 20(5):374-387.
Ozin GA, Arsenault AC (2005). Nanochemistry – A Chemical Approach to Nanomaterials. The Royal Society of Chemistry, Cambrigde, UK.
Patricio BFC, Albernaz MS, Oliveira RS (2013). Development of Nanoradio pharmaceuticals by Labeling Polymer Nanoparticles with Tc-99m. World J. Nucl. Med. 12:24-26.
Plentz F, Fazzio A (2013). Considerations on the Nanotechnology Brazilian Program (*Considerações sobre o programa brasileiro de nanotecnologia*). Revista da Sociedade Brasileira para o Progresso da Ciência 65(3):23-27 (*In Portuguese*).
Renn O, Roco MC (2006). Nanotechnology and need for risk governance. J. Nanopart. Res. 8:153-191.
Serrano AL, Olivas RM, Landaluze JS, Cámara C (2014). Nanoparticles: a global vision. Characterization, separation, and quantification methods. Potential environmental and health impact. Anal. Methods 6:38-56.
Sozer N, Kokini JL (2009). Nanotechnology and its applications in the food sector. Trends Biotechnol. 27(2):82-89.
Stylios GK, Giannoudis PV, Wan T (2005). Applications of nanotechnologies in medical practice. Injury 36(4):S6-S13.
Zang L. Ed. Energy Efficiency and Renewable Energy Through Nanotechnology (2011). Springer, London.