DEVELOPMENT OF NANOTECHNOLOGY IN AGRICULTURE FOR SMALL NORTHERN EUROPEAN COUNTRY

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Abstract. The article reviews the status of nanotechnology development for rural development and agriculture and food production from the perspective of a small Northern European Country related. Interests of consumers remain paramount in the EU competition policy. Respect for the consumers' economic and legal interests will encourage their confident participation in the internal EU market. This is why a substantial regulatory framework is already in place to promote the consumer interest and why further work will be needed to update and fill the acknowledged gaps in the existing framework. The process of the expansion of the economical space is a phenomenon of the contemporary so called "open society" that puts forward new demands for the Baltic region state development integrating into the European Union. Introduction of advanced technologies advances the necessity for more up-to-date science structural and social organizational forms, integrating academic education, research and entrepreneurship into a unified complex. An important research problem for effective use of nanotechnologies in agriculture is the assessment of possible risks and food safety, also the possibility to acquire in the process of food production dependable information on all the attributes of a product, which affect its safety and quality. In addition, all nanotechnologies have some impact on consumers. Some nanotechnologies have positive impact on consumers, but using of some nanotechnologies this impact on consumers is more negative, than positive. Therefore, the main aim is to improve policymakers' understanding of the nature of consumer interests relating to nanotechnologies. To pursue this, the impact of nanotechnology on economy is investigated from the perspective of a small Northern European country.

Key words: nanotechnology, impact, agriculture, rural development.

Introduction

Nanotechnology is defined by the International Organization for Standardization as the „application of scientific knowledge to manipulate and control matter in the nanoscale in order to make use of size- and structure-dependent properties and phenomena, as distinct from those associated with individual atoms or molecules or with bulk materials [1]. Nanotechnology can be understood as precise manipulation of atoms and molecules to create materials with defined properties. A basic definition: Nanotechnology is the engineering of functional systems at the molecular scale [2]. This covers both, the current work and concepts that are more advanced. The word "nano" refers to a billionth of a meter or at an atomic scale with nanotechnology usually referring to the manipulation of matter at a scale of 1 to 100 nanometers. The origins of nanotechnology can be traced to a talk at Caltech by the physicist Richard Feynman in 1959 titled "There's plenty of room at the bottom" where he proposed the possibility of precise manipulation of atoms and molecules and suggested the creation of "nano-scale" machinery. Eric Drexler, as a student at the MIT in the early 1980's built on the vision and published a paper "Molecular Manufacturing" in the Proceedings of the National Academy of Sciences that were greatly expanded in his book Engines of Creation: The Coming Era of Nanotechnology, published in 1986. These conceptual foundations for the field were given reality with the invention of the Scanning Tunneling Microscope (STM) in 1981 and the Atomic Force Microscope (AFM) in 1986. The field received further impetus with the discovery of buckyballs by Richard Smalley in 1985 at the Rice University and by the direct manipulation of atoms by Don Eigler at the IBM in 1989 (Fanfair, Desai, Kelty), [2].

Materials and Methods

In the paper the authors use forecasting methodology, induction and deduction, structural-functional, analytical research, perceptual modeling, conformity assessments and fractal images methods. The basic results are formed in a complete agreement of the existing notions, data, level of knowledge about the investigation process and objects with the trend being towards the convergence of rural development and nanotechnology in Latvia to estimate a technology factor, a measure of the economic impact of emerging nanotechnologies, the efficiency and likelihood of translating technology funding into the economy. The analytical research was focused on nanotechnologies and its impact on world economy, assessing of condition and perspective of nanotechnologies in Latvia as a small Northern European country.

Results and Discussion

Nanotechnology promises production of materials with improved properties or of products with embedded intelligence such as smart materials that can respond to changes affecting the material such as filters that can remove bacteria but allow other particles of comparable size to get through. Hundreds of billions of dollars are being invested in nanotechnology development based on the expectation that nanotechnology will lower costs or lead to materials with improved performance or to entirely new products not otherwise possible. Mike Roco has described four generations of nanotechnology development (Fig. 1). The current era, as Roco depicts it, is that of passive nanostructures, materials designed to perform one task. The second phase, which we are just entering, introduces active nanostructures for multitasking; for example, actuators, drug delivery devices, and sensors. The third generation is expected to begin emerging around 2010 and will feature nanosystems with thousands of interacting components. A few years after that, the first integrated nanosystems, functioning (according to Roco) much like a mammalian cell with hierarchical systems within systems, are expected to be developed [2; 3].

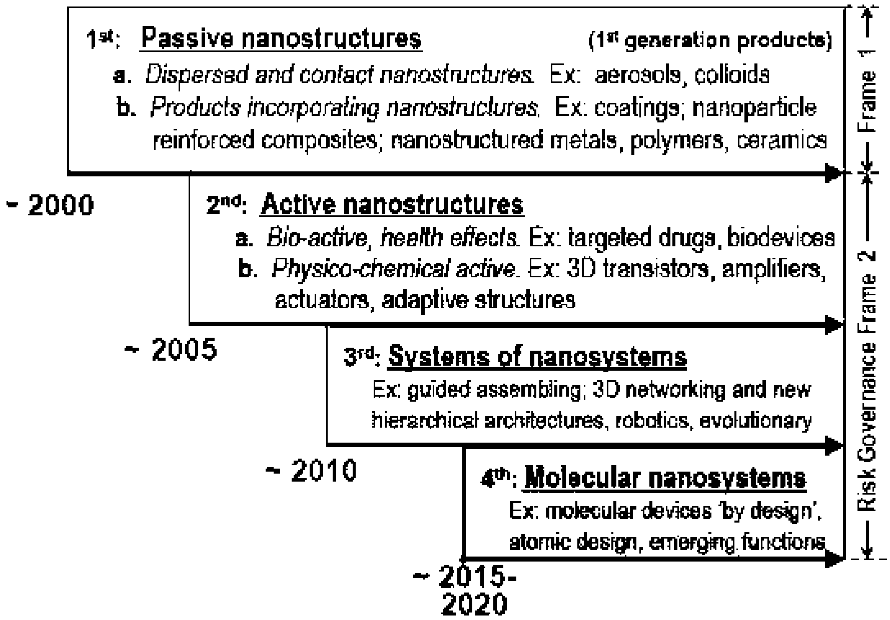

Fig. 1. **Four generation products of nanotechnology [3]**

According to the "European Nanotechnology Landscape Report" published December, 2011, nanotechnology will transform manufacturing, energy production, medicine, agriculture, food processing and be a key to addressing the key challenges facing Europe [4]. Globally, huge sums are being invested in nanotechnology with annual funding exceeding 10 billion USD by 2010 and estimated to be about 13 billion USD by 2015 [5], Fig. 2.

The same report shows Latvia to be a virtual non-player in nanotechnology. In 2011 Latvia allocated 0.4 million Euro to nanotechnology development through its science budget [4]. Latvia had the lowest rate of publication of nanotechnology research in Europe with 0.31 publications per 100,000 residents (7 articles) compared to Estonia with 2.91 (39 articles) and Switzerland with 13.39 (1,031 articles). The National Science Foundation predicts that the global market for goods and services using nanotechnologies will grow to 1 trillion USD by 2015. The U.S. invests approximately 3 billion USD annually in nanotechnology research and development, which accounts for approximately one-third of the total public and private sector investments worldwide.

The world's governments currently spend 10 billion USD per year on nanotechnology research and development, with that figure set to grow by 20 % over the next three years. By the end of 2011 the total government funding for nanotechnology research worldwide will be 65 billion, rising to

100 billion USD by 2014. When figures for corporate research and various other forms of private funding are taken into account, which were thought to have surpassed the government funding figures as far back as 2004, we estimate that nearly a quarter of a trillion dollars will have been invested into nanotechnology by 2015 [5].

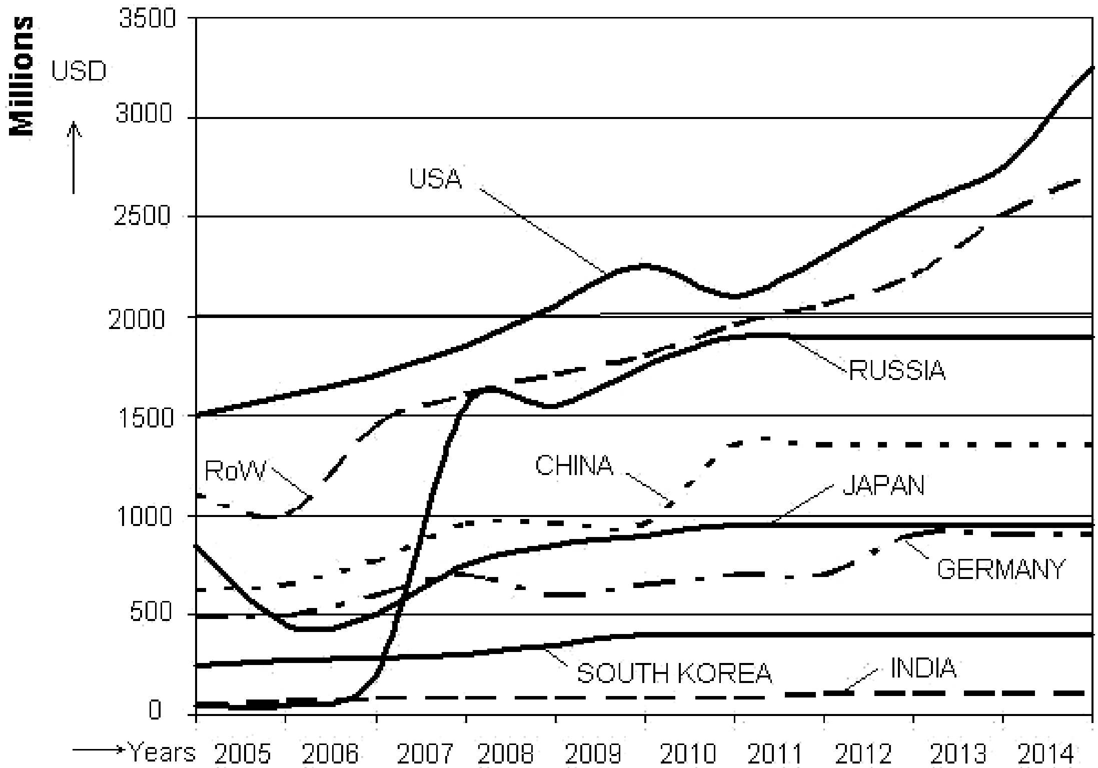

Fig. 2. **Contribution to development of nanotechnologies from the separate countries (adapted from [5])**

Integrated data for the 2011 from the World Economic Forum annual Global Competitiveness Report allow gaining insights into how well various countries are able to capitalize on their investment in research (Fig. 2). Some countries have excellent research institutions but little in the way of industry-academic cooperation, while others may have large companies who spend little on R&D.

By combining macroeconomic data such as overall global competitiveness, quality of scientific institutions, capacity for innovation and levels of company spending on R&D with a number of other relevant factors allows for estimation of an technology factor, a measure of the economic impact of emerging technologies, and the efficiency and likelihood of translating technology funding into the economy. While this measure holds true for a wide range of research-based technologies it takes no account of the level of nanotechnology funding which varies widely across different countries.

The progress of development we see from simple to complex systems with the trend being towards the convergence of informatics, biotechnology, nanotechnology and artificial intelligence [4; 8 – 11]. According to our opinion as a key area of nanotechnology research impacting rural development can be:

- energy – solar cells, improved batteries, motors, transport; we see the potential for significant improvements to technology that will make rural development more attractive with better fuel economy and lower cost distributed power systems;
- environment - toxin cleanup, reduced material requirements, improved methods of mining and mineral extraction that are less damaging to the environment;
- wide use of nanomaterials in agriculture , for example, for installations for veterinary service, devices for fixation, special installation for transportation of large animals, for agricultural buildings and rooms designed by use of cheap inflatable airbags;
- wide use in agriculture of new nanomaterials kevlar, vectran, graphene;

- medicine and veterinary science;
- food production and agriculture. Packaging for food safety. Improved crop yields. "Smart farming" with reduced fuel consumption, higher productivity, food produced to meet specific demand.

Table 1

Global nanotech impact factor (A) and exploitation index (B), [5]

A	
Country	**Nanotech impact factor**
United States	100
China	89
Russia	83
Germany	30
Japan	29
EC	27
South Korea	25
Taiwan	9
United Kingdom	6
India	5

B	
Country	**EmTech exploitation index**
United States	5.00
Germany	4.93
Taiwan	4.90
Japan	4.88
South Korea	4.60
United Kingdom	4.55
China	4.30
EC	4.23
India	3.95
Russia	3.57

For the purpose of this paper we treat synthetic biology as a subfield of nanotechnology. Synthetic biology is the engineering of living processes to develop life forms not found in nature [6; 7]. In principle in the long term food for humans and feed for animals may be possible to produce through synthetic biology possibly eliminating the need for field grown crops and animal husbandry [12; 13]. We do not anticipate this level of development within a planning horizon to 2050. A new method of fractal imaging has been developed at the Latvia University of Agriculture for molecular modeling and conformity assessing of nanostructure in the hidden layer, Fig. 3 – 5, (prof. G. A. Moskvin).

Fig. 3. **Method of fractal imaging for molecular modeling and conformity assessing of nanostructure in the hidden layer (source: prof. G. Moskvin)**

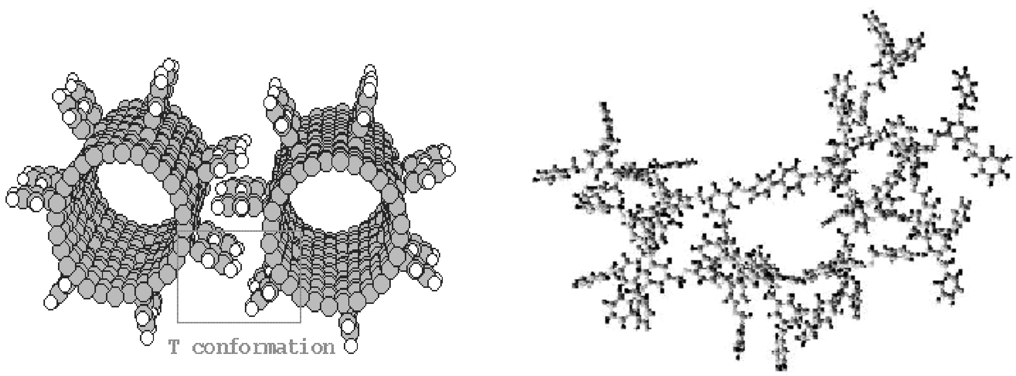

Fig. 4. **Basic work principle of nanoassembler (source: Foresight Institute, [8])**

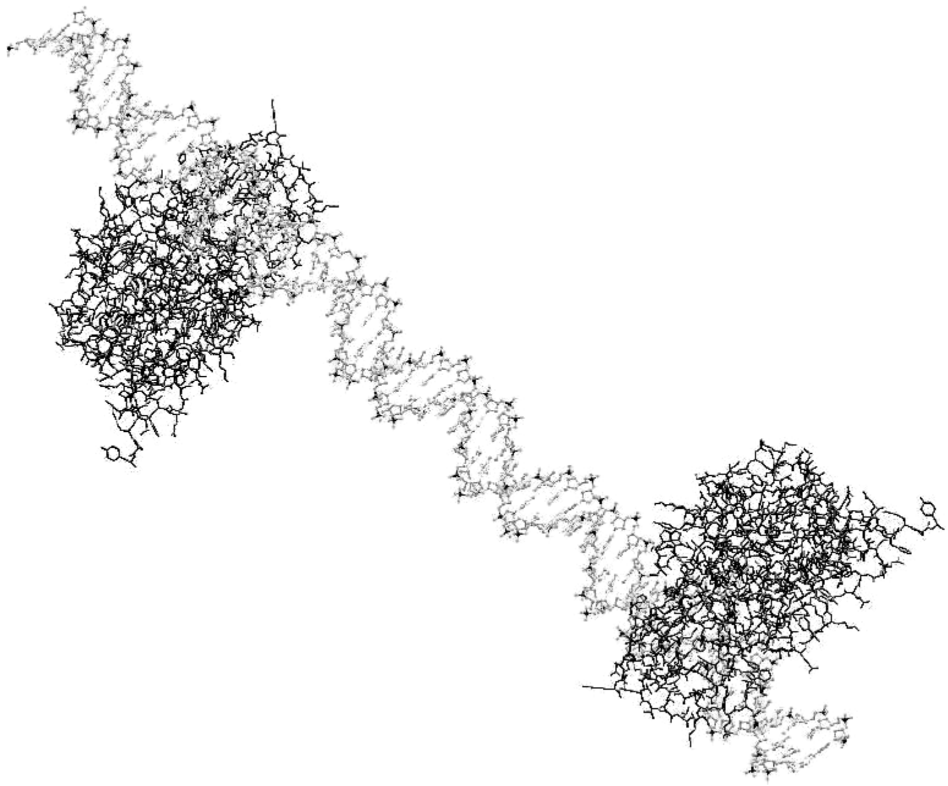

Fig. 5. **Fractal model of DNA (source: prof. G. Moskvin)**

Nearly seven in 10 people have an initial opinion about synthetic biology risk-benefit tradeoff. The plurality believe that risks and benefits will be about equal (32 %), and the rest are divided evenly between thinking the benefits will outweigh the risks (18 %) and the risks will outweigh the benefits (19 %).

Among people who make an initial assessment of synthetic biology, the plurality think the risks and benefits will be about equal, and the remainder are divided evenly between benefits and risks [9 – 13]. When potential risks and benefits of synthetic biology are outlined, however, the greatest shift in public opinion is toward risk, Fig. 6.

By 2050 UN and other demographic experts estimate that the global population will have reached approximately 9 billion people. Nanotechnology will be critical to feed, clothe and house this number of people living in an environment stressed by climate change and population growth with a significantly increased percentage living at higher standards of living as compared to today. Is a nanotechnology field for large countries or do small countries having a role to play?

Nanotechnology development is dominated by the US, China, Russia, and the EU. Israel is a niche player. The field is extremely broad. Dominant "killer apps" are unlikely to emerge that could give a single country dominance. However, there is the likelihood of emergence of platforms, analogous to the iPhone to which thousands of "apps" from many small, independent producers could have a role. Latvia is unlikely to produce the platform, far more likely, Latvia is likely to become a hotbed of activity for development of "apps" that utilize the platform technology developed by the US or other large markets.

Latvian agriculture is concentrated in grain, rapeseed, potatoes, vegetables; pork, poultry, milk, eggs, fish. The growing season is short averaging 185-190 days and soils are relatively poor favoring grazing and forage crops other than in the region of Zemgale that is largely flat. Nanotechnology may play a role in extending the effective growing season through hardier crops that can better survive adverse weather conditions. Nanotechnology may also play a role in food storage including coatings for food produced that are resistant to pests and also prevent oxidation. In relation to significance of nanotechnology in agriculture and food production nanotechnology promises to improve yields with reduced use of fertilizers, energy inputs, herbicides and other pesticides.

Some believe that with the "green revolution" losing its potential to increase yields, especially under climate change, weakening of effects of herbicides and pesticides, emergence of diseases that attack monoculture agriculture and related factors. Some claim that nanotechnology based agriculture and food production will be necessary, if humankind is to survive into the coming decades. On the basis of analytical researches and conclusions the strategy for managing risks and benefits of nanotechnology at the level of a small country can be defined.

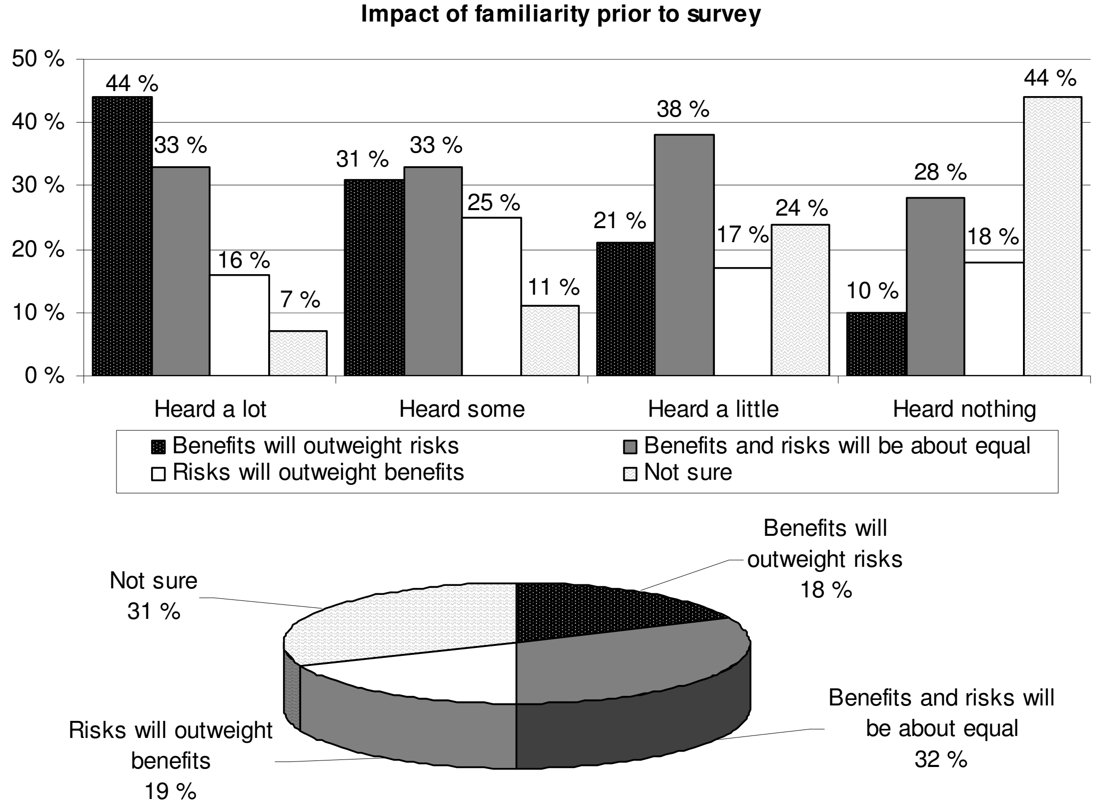

Fig. 6. **Impact of familiarity prior to survey (Source: The WWI Center for Scholars)**

The coming decades will see the introduction of thousands of new nanotechnology-based products. Many of these products and their production processes will pose risks for which Latvia is unlikely to be prepared to face. Latvia is presently not represented in the European Food Safety Authority's "Nano Network" which is charged by EFSA to assess and advise the EFSA and member states on food and feed safety issues arising from utilization of nanotechnologies in food and feed [13].

Latvian agricultural engineering has significant potential in the following areas of nanotechnology:

- improved photovoltaic systems for improved distributed energy systems needed for rural development;
- packaging systems to reduce wastage from crops raised;
- synthetic biology for agricultural fuels;
- synthetic biology for reduction of use of antibiotics in animal husbandry;
- coatings for antifouling of rural water systems eliminating the need for toxic chemicals;
- it is necessary to study a role of new nanomaterials - vectran and graphene in rural development.

Conclusions

1. Nanotechnology will have large impact on rural development. Synthetic biology can revolutionize food production threatening traditional methods of agriculture.

2. It is necessary to create international standards for nanotechnology and in addition special international organizations in the area of nanotechnologies to reduce national differences in assessing of nanotechnologies and risk governance practices.
3. Nanotechnology can pose significant risks to food production, food distribution and healthcare systems that are poorly understood that are particularly important to a small country that can ill afford to mount the research effort required to manage the risks that are likely to emerge with the accelerating global development of nanotechnology. For these purposes it is necessary to create the research infrastructure for toxicology and risk assessment.
4. For Latvia as a small Northern European Country it is necessary to define what nanotechnology products have export potential, to create a research infrastructure for new product development.
5. Latvia as a small Northern European Country related in the future to use of nanotechnologies in agriculture must prepare for both, the risks and opportunities inherent in nanotechnology.
6. In aspects of nanotechnology study courses it is necessary to define what kind of skills and knowledge are needed in a small, agricultural country to take advantage of nanotechnology and to manage risks that are likely to emerge with increasing commercialization of nanotechnology.
7. At present in Latvia in the field of nanotechnologies very few researches are carried out. Some small projects are financed, but there is no coordination of researches in the aspect of real needs of the country. Therefore, first of all it is necessary to develop the national program and scientific-research business center of nanotechnologies with attraction of local and European investments.

References

1. ISO, (2010), Nanotechnologies – Vocabulary Part 1: Core terms. International Organization for Standardization, 2010 (DD ISO/TS 80004-1:2010).
2. K. Eric Drexler, http://e-drexler.com/p/idx04/00/0404drexlerBioCV.html (retrieved 31.03.2012).
3. Respobsible Nanotachnology, http://crnano.typepad.com/crnblog/2006/03/new_risks_new_f.html (retrieved 31.03.2012).
4. Winans, B., et al (2011), „European Nanotechnology Landscape Report", Observatory NANO.
5. Hunter, T., Global Funding of Nanotechnology and its Impact", July 2011, Cientifica.
6. Nanotechnologies Industry Association, (2007), "NIA Forecast of Emerging Technologies: Nanotechnologies".
7. Kuzma, J., Verhagen, P., (2006), Nanotechnology in agriculture and food production: Anticipated applications, Project on Emerging Nanotechnologies.
8. http://www.foresight.org/about/index.html (31.03.2012).
9. Moskvin G., Spakovica E., Moskvin A. Development of Intelligent Technologies and Systems in Agriculture, Engineering for Rural Development. Proceedings of the International Scientific Conference (2008), Jelgava, 29.-30.05.2008, pp.108 – 113.
10. Moskvin G., Spakovica E. New Method and Low-Cost Intelligent Instruments for the Fraud Detection and Conformity Control of Agricultural Products**.** 2002 ASAE Annual Meeting and CIGR WORLD Congress**.** July 29-July 31, Hyatt Regency, Chicago, IL, USA, ASAE Paper Number 023077.
11. Moskvin G, Spakovica E. Intelligent Technology for the Conformity Assessment of Agricultural Products. Advances in Computer, Information, and Systems Sciences, and Engineering. Hardcover ISBN: 1-4020-5260-X, Springer Berlin - Heidelberg - New York, 2006, p.109-114.
12. Harper, T., Hailing, Y., Jordanov, M., "Using Emerging Technologies to Address Global Risks", Cientifica, October 2011.
13. EFSA, (2012),"Technical Report: EFSA Scientific Network of Risk Assessment of Nanotechnologies in Food and Feed".