Public and Scientific Community Attitudes towards Nanotechnology Applications

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Abstract. The emergence of nanotechnologies having high market potential is followed by concerns associated with their adoption, acceptance and diffusion. However, the public and academic anxiety about the risk of nanomaterial application in food, cosmetics, agricultural and other industries, may significantly affect the opportunities and prospects for the development of nanotechnologies. The paper is devoted to the study of social concerns related to nanotechnologies. It is concluded that there is no consensus among academia regarding opportunities and risks of nanomaterial implementation. The hazards and consequences of nanotechnology applications have been described. It has been demonstrated that studies of nanotoxicity are frequently carried out in far from reality conditions and tend to be perceived as prognostic. Nevertheless, assuming the results of this kind of studies being popularized through mass media, it can cause the formation of public opposition with respect to nanotechnology application.

Keywords: nanotechnology, public community attitude, researchers' perception, nanomaterials application, risks, toxicity.

1. Introduction

Today nanotechnology is called the Industrial Revolution of the twenty-first century. According to Khan & Asmatulu (2013), within 10 or 15 years, it is expected that the industrial production of nanotechnology will be worth over $1 trillion. The development and implementation of nanotechnologies contribute to the progress in various fields: biomedical, pharmaceuticals, textile, aerospace, manufacturing, cosmetics, oil, defense, agricultural, construction and electronics industries. Therefore, as noted by Bozeman et al (2007), application of nanotechnologies has an enormous commercial potential for marketers and investors. In the very nearest future, nanotechnologies will be able to drastically change science, education, manufacturing, and lifestyles of people around the world (Khan & Asmatulu, 2013). That is why, as mentioned by Nerlich & Lemańczyk (2015), today we should consider nanotechnology as not just an emerging technology but also as a new social and cultural phenomenon.

The attitude of public and scientific communities in particular, is of a high importance for the evolution of new and emerging science and technology. This is due to the concerns and hopes for nanotechnology among public and scientific community, as well as their attitude towards nanotechnology applications, being able both accelerate and suppress the development of nanomaterial production and consumption. However, the relations between nanotechnology, society and (nano)scientific community are still questionable.

There is an ambivalent and ambiguous viewpoint of the society regarding nanotechnology application; profits and risks associated with nanomaterials are not unanimous. On the one hand, nanotechnologies provide much better quality and properties of the variety of materials, which, even today, leads to the development of different branches of economy and improvement of the population quality of life. On the other hand, numerous experimental studies of toxicologists have demonstrated that nanomaterial application may be insecure for human health and the environment.

A number of studies on toxicity towards mammals, testified nanoparticles inhibit the phagocytic function of alveolar macrophages that cause an acute immune deficiency (Liu et al, 2013), induce apoptosis, which leads to tissue destruction (Zhang et al, 2012), cause damage to cell membranes as a result of oxidative stress (Huang et al, 2010). Animal and human studies show that inhaled nanoparticles are less efficiently removed than larger particles by the macrophage clearance mechanisms in the lungs, causing lung damage, and that nanoparticles can translocate through the circulatory, lymphatic, and nervous systems to many tissues and organs, including the brain, as evidenced by Liu et al (2008), Magrez et al (2006), Medina et al (2007), Oberdorster et al (2007), and Wong-Ekkabut et al (2008). Hence, as mentioned by Boverhof & David (2010), nanoparticles represent the new class of pollutants with unknown toxic doses, which requires numerous experiments to be conducted. At the same time, the obtained results may create significant difficulties for the development and application of nanotechnologies.

In a research study by Chena et al (2013) it is noted that many new and emerging technologies, e.g. nuclear power, genetically modified organisms (GMO), embryonic stem-cell research etc., have been gained through a strong society opposition. According to Chena et al (2013), "We should take into account scientific community and public attitudes towards nanotechnology because cultural and social predispositions have become the most important cognitive shortcuts to evaluate a new technology such as nanotechnology". Consequently, public perception of nanotechnology may influence the realization of technological advances that has been proved by Macoubrie (2006).

Together with either acceptance or antagonism of society in relation to nanotechnologies, the attitude of scientific community is of a considerable importance. The formation of initial opinion on danger or safety of nanotechnology application particularly takes place within academia, which is afterwards transmitted to the society through mass media. It should be noted, that there is no unified and univocal attitude regarding the safety of nanomaterial application within the scientific community itself.

The aim of the present work was to determine the motives of academia attitude towards the risks of nanomaterial implementation. The attitude of the scientific community indeed may cause a strong opposition among public towards nanotechnologies.

2. Scientific Community Attitudes towards Nanotechnology Applications

Various materials at a nanoscale possess new, often extraordinary, chemical physical and biological properties that can be used particularly in targeted drug delivery systems, cancer and virulent infection control, gene and molecular engineering, improvement of the state of the environment, in cosmetics and food industries. Apparently, the extensive research and use of nanotechnologies and nanomaterials eventually will lead to a close contact of human and other biological objects with nanosized objects. Therefore, a study of arising potential risks represents a highly significant task. According to Ramsden et al (2014), "risk is usually defined as the hazard associated with an event multiplied by the probability of the event occurring".

Nanotechnologies introduce not only certain benefits, but also potential threats of adverse health and environmental effects. Hence, to control the risks coming from the manufacturing and traffic of nano-enhanced consumer products it is necessary as early as the planning stage to conduct comprehensive research on risk assessment of novel nanoproducts. As mentioned by Kahru & Dubourguier (2009), in many countries the elaboration of regulatory and procedural framework intended to safety assessment of manufacturing and application of nanotechnologies is ongoing.

The main triggering event of nanomaterial hazards towards human health and the environment is occurring of sources of the release of nanosized objects into the ambient environment while engineering, studying and implementing nano-enhanced products. In this work by "nanomaterials" authors imply «materials consisting of 50 % or more of particles having a size between 1 nm-100 nm», as indicated in the European Commission Recommendation (2011) concerning the immediate implementation of a safe, integrated and responsible approach for nanosciences and nanotechnologies.

At the moment, there are a number of studies indicating potential hazards of nanotechnology application (Liu et al, 2008) (Magrez et al, 2006) (Medina et al, 2007) (Oberdorster et al, 2007) (Wong-Ekkabut et al, 2008). In contrast, Colvin (2003), Dumortier et al (2006), Friedman & Egolf (2005), Maynard et al (2006), Priestly & Harford (2006) have demonstrated risk free applications of nanomaterials. Therefore, we clearly see that there is no consensus within scientific community towards safety/hazard of nanotechnology application.

This work was focused on the evaluation of research articles cited in databases Science Direct and Web of Science over the period of 2011-2015. The results of the study show that alongside an increase in the number of publications devoted to nanotechnologies in all, there is an increase in the number of studies particularly focused on risks and toxicity of nanomaterials.

The articles are devoted to potential hazards and risks attributed to nanotechnology applications in food industry, medicine, cosmetics, etc. Scientific community is deeply concerned with the impact of nanotechnologies on human health and the environment. The increased risk of nanomaterial occurrence in the environment is mainly due to two factors:

Firstly, according to Oberdörster et al (2005) and Nel et al (2006), in contrast to coarse particles, nanoparticles owing to the size may sufficiently penetrate a blood system via respiratory system, skin, and gastro-intestinal tract that provides increased risk conditions for human health as well as other organisms.

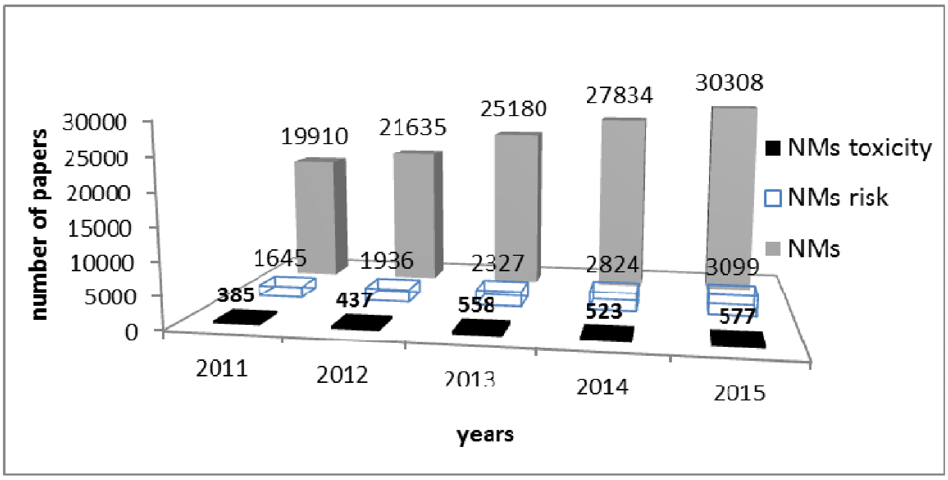

Fig 1. Dynamics of publication activity on nanomaterials (NMs), nanomaterials risks (NMs risk) and nanomaterials toxicity (NMs toxicity) (Science Direct data, 2011-2015)

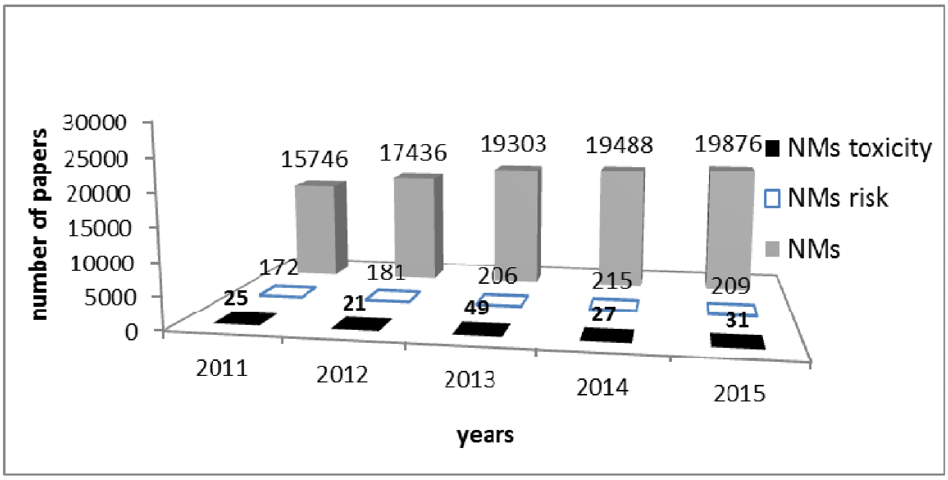

Fig 2. Dynamics of publication activity on nanomaterials (NMs), nanomaterials risks (NMs risk) and nanomaterials toxicity (NMs toxicity) (Web of Science data, 2011-2015)

Secondly, as noted in a research study by Handy et al (2008), nanoparticles demonstrate physicochemical and, consequently, toxicological properties, different from bulk particles of the same chemical composition and dependent from particle size, shape, its adhesive, catalytic, and electrical properties. In vivo (based on animals) and in vitro (based on cells) experiments conclusively show that once entered the human body, nanoparticles may interrupt biochemical reactions, aggravate microbial flora, induce mechanical damage to the natural mechanisms of the body, or lead to the formation of free radicals, highly active elements, that break cells and cause tissue and organ inflammation.

In the last 10 years, experimental studies on toxicity and ecotoxicity of nanomaterials have testified exhibition of high toxic effect by nanoparticles towards most diverse ecosystems (Handy et al, 2008) (Ray et al, 2009) (Ferry et al, 2009) (Huang et al, 2005) (Lin & Xing, 2007). Thus, as proved by Kumari et al (2011), nanoparticles are able to affect microbial environment in soil cultures demonstrating toxic effects when interacting with living organisms and introducing pollutants into the soil, e.g. heavy metals.

According to Pal et al (2007), one of the important toxic effects exerted by nanoparticles is degradation and change of characteristics of cell walls and membranes. Lin & Xing (2008) proved that absorption of nanoparticles by plant cells responsible for photosynthesis, can lead to decrease of light intake and disruption of gas exchange, and, consequently, suppress the course of photosynthesis and impact on plant respiration processes. Accumulated experimental data on rodents, monkeys and pigs indicate acute toxicity of nanomaterials when entering the organisms of mammals. In this respect, the toxicity of nanoparticles is increasing depending on place and the route in a row: "skin – gastro-intestinal tract – lungs – blood", as mentioned by Oberdörster et al (2005).

It has been shown on mammals that nanoparticles may enter the human body with food and drink. When entering gastro-intestinal tract, some nanoparticles can be fully absorbed (without dissolution) and dispersed with blood throughout the body causing general toxic, irritating, sensitizing, carcinogenic, mutagenic effects, as well as affecting human reproductive system. Skin is a potentially important route of nanoparticles into the organism (Hoet et al, 2007). It has been proved by Gamer et al (2006) and Cross et al (2007) that particles of less than 1 μm are able to penetrate through the stratum corneal and diffuse into lymph and blood.

In the experiments with rodents by Takenaka et al (2002), it has been established that distribution in the air followed by respiratory intake with the air into the lungs is the most common way of nanoparticle entering the human body. The behavior of inhaled nanoparticles considerably differs from the one of gaseous or volatile compounds. Assuming the mechanical and physical conditions of solid particle deposition, it is expected that with the decrease of particle size (from micro to nano) the penetration into respiratory tract is deeper: nasal – tracheobronchial – alveolar region (Oberdörster et al, 2005).

The generalized scheme of testified and potential pathways of nanoparticles in the human body as well as their dispersion and elimination, corresponds to the scheme of these processes for any other substances in the atomic-molecular state. Small size facilitates nanoparticle enter into cells and its transfer to blood circulatory system, lymphatic system, central nervous system, wherein nanoparticles reach potentially sensitive targets, i.e. bone marrow, lymph nodes, spleen and heart. In other words, nanoparticles may overcome defensive barriers of the respiratory, urinary, circulatory and other human systems.

However, nanotechnology up to date does not provide clear answer to what extent the transfer from the experimental results obtained on rodents and other mammals to humans, is appropriate, since respiratory systems of rodents and humans are different. Therefore, to a greater extent, the obtained data are prognostic.

Specific physical, physicochemical, chemical and biological properties of nanoparticles contribute to nanomaterial exhibition of toxicity towards living organisms and ecosystem, which is not common in case of bulk materials and soluble substances entered the environment. Dimensional specifics of nanomaterials definitely complicate their quantitative determination in various environmental objects. Besides shape and size of particles, the specific characteristics particularly include the ability of nanomaterials to form colloidal solutions and aggregates. This makes their quantification difficult and cause a lot of controversy.

When studying ecotoxicological properties of nanomaterials the major challenge is maintaining of high aggregative stability of aero- and lyosols. In order to manage this, suspension and aerosol delivery systems together with various stabilization modes, such as solvents, sonication, magnetic stirring, are used. Accordingly, due to necessary assumptions and far from reality conditions the obtained results are characterized as forecasting.

Hence, we can see that the reason for academia attitude to risks of nanomaterial implementation is a great number of studies showing high toxic effect of nanoparticles towards various ecosystems. Popularization of such point of view through mass media can lead to an inhibition of nanotechnology development and application. Upon enquiry the serious risks and threats to human health and the environment, mass media are able to generate many fears among the society concerning the toxicity of nanomaterials. According to Chena et al (2013), “When people cannot assess benefits and risks directly, they have to rely on information given by experts or other sources”. Nevertheless, many studies on nanotoxicity have not testified hazards of nanotechnology applications in the real environment.

Provided the experts from scientific community give mainly the information on potential danger of nanotechnologies, this, in turn, can generate strong public opposition to nanotechnology applications. Both social benefits and possible risks of nanotechnologies should be taken into account and clearly reported to the public and authorities. If these preventive steps are not taken, the society and the authorities can treat nanomaterials as dangerous, which would create strong barriers for the commercialization and implementation of useful in other respects nanotechnology products.

3. Public Perceptions on Nanotechnology Applications

Positive perception of new technologies by society provides opportunities for the development and application of these technologies. Therefore, public attitude towards nanotechnology is extremely important at the moment. The viewpoint of society regarding the possibilities of nanotechnology application affects the economic value of these emerging technologies. Public attitude to nanotechnology has been an object of study in several papers (Chena et al, 2013) (Cobb & Macoubrie, 2004) (Priest, 2006) (Siegrist et al, 2007). According to a research study by Chena et al (2013), "The public's more positive attitude toward technology, more nanotechnology knowledge, and more social trust in the related institutions are positive contributors to its perceived benefits from applying nanotechnology, and vice versa".

Today, there are a number of fears associated with nanotechnology application:

1. Fear of forced implementation of non-natural nanotechnological foodstuffs.

This fear has been originated in the course of genetically modified food development and production. Due to lack of knowledge, the population takes GMO containing products with great suspicion, and popularization of such kind of fears in mass media intensifies the situation. Once Losey et al (1999) had published scientific report on harmful effects of GMO products towards vital activity of butterflies, the scientific community started proving harmful effects of GMO products with great eagerness.

2. Fear of increased toxicity of nanomaterials, their harmful effects towards human health and negative impact on the environment.

This fear has spawned countless blogs on the Internet devoted to the issues of nanomaterial toxicity. The question of the influence of nanomaterials on human health induces a lot of controversy and debates. However, once sown in the public mind, not exactly justified fear will be difficult to overcome at a later stage. This fear can cause inhibition of the real implementation of certain types of nanomaterials.

3. Fear of uncontrollable nano-robots.

This fear had occurred in society since the book by Drexler (1986) was published. In this book the author shows that the concept of creation of self-replicating electronic systems may lead to disaster in case of loss of control. This point of view had been extended in cinematograph, which gave the world dozens of movies about problems arising in case of uncontrolled rapid spread of self-replicating nanosystems.

4. Fear of using nanomaterials in biological warfare and terrorism.

After the terrorist attacks in September 11, 2001 in the US and spread of anthrax worldwide, the extra attention is paid to manufacturing, transporting, trading and use of micro- and nanopowders, as mentioned by Rickerby (2004).

5. Fear of emergence of superhuman (Satava & Wolf, 2003).

The fear is associated with the ideas of transhumanism. According to Walters & Palmer (1997), since the first experiment of genetic engineering was carried out in the 1980s, the issues of ethics of intervention of emerging technologies in the entity of human nature had been relevant. Also, nanotechnologies are able to make significant changes in the processes of aging, birth and death.

6. Fear of invasion of privacy.

This fear is especially important because of the development of miniature electronic communication and information transfer devices (nano-cameras, nano-microphones, etc.). Public is anxious about personal space security issues considering that people use all means of communication, including the Internet and telephone, 24 hours a day.

As nanotechnologies are at an early stage of the development, there is no clear opinion of society on generated prospects and possibilities of nanotechnology applications. Studies by Cobb & Macoubrie (2004), Lee et al (2005), Waldron et al (2006), Scheufele & Lewenstein (2005) indicate that knowledge of nanotechnology among society is limited and public attitudes are not well-defined. Bainbridge (2002) noted that, in general, public attitudes towards nanotechnology are more positive than negative.

Mass media form public attitudes. The analysis of news content in many countries (Canada, Denmark, US, Germany, Spain, Italy, etc.) shows that public attitudes are focused on benefits of nanotechnologies in news reporting (Laing, 2005) (Dudo et al, 2011) (Veltri, 2013) (Kulve, 2006) (Donk et al, 2012). In all, positive attitudes towards nanotechnology should be noted (Tyshenko, 2014).

Mass media introduce the keynote and establish the initial parameters of discourse with respect to nanotechnologies. As noted by Scheufele & Lewenstein (2005), mass media can influence public attitudes to nanotechnologies by applying information from a certain angle and pointing up certain aspects.

Nowadays, study and application of nanosized objects are acknowledged as priority for scientific and technological development in Russia, and have great impact on the further development of various branches: economy, medicine, scientific research, information technology, ecology, defense industry, etc. To determine the attitude of society towards nanotechnologies in Russia, we analyzed news content on the most popular TV channels: Channel 1, Russia 24, NTV, as well as particularized web portal – http://www.nanonewsnet.ru/.

The results of the study show that there are not much of references on nanotechnologies in the news section, however, those which presented are considered in a positive way. Nanotechnologies in Russian mass media represent a key to innovations and technology breakthroughs, scientific revolutions in various fields: medicine, information technology, robotics, arms industry, agriculture, etc. Generally, they are associated with hopes for improvement of life quality, overcoming many serious diseases, and development of national economy.

4. Conclusion

In summary, as far as nanotechnologies are emerging technologies, there is no well-defined public attitude to safety of their application. The increasing number of studies on nanotoxicology can cause more and more fears in public mind. At present, the society has positive attitude to nanotechnologies, but there is a kind of anxiety of population, which is related to the possible negative social impacts of nanotechnology applications. To prevent the fate of GMO technologies for nanotechnologies, it is necessary: first, to involve the public in the condemnation of the difficulties the scientific community confronted with; secondly, to inform the society about regulations of nanotechnology applications by authorities; thirdly, to continue formation of positive attitude to nanotechnologies through mass media. The interaction of society, scientific community, mass media and the authorities is a key point for successful development of such an emerging discipline as nanotechnology.

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