Content Unit
[Nano safety]

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Last processing date: [12. 12. 2021]

Nano safety

First introduction
Throughout the human history, anything new and unknown has caused anxiety and fear in a man. This is caused by an evolutionary mechanism that protects us on the one side, but on the other, it can thwart good and innovative ideas that could improve human lives. Comprehensible education and popularisation of the fundamental principles of nanotechnology solutions and their safety can help dispel any concerns. Neglecting education would open the path for development of large social groups that would reinforce one another in their fears on social networks and translate their concerns into programmatic resistance against the innovative solutions. Based on irrational fears, virtually anything can be restricted or banned following the principle of precaution. In the end, this could reduce the prospects of favourable economic development and lower the potential of European economic growth. In order to avoid this, we need to be aware of the circumstances under which nanomaterials can be harmful for us as well as the ways of preventing such risks.

Practical relevance – This is what you will need the knowledge and skills for
In this unit, you will learn where the potential risks of using nanotechnologies lie and how to prevent them. Understanding the fundamentals of the safety solutions for nanotechnology as well as the elementary algorithms suitable for verifying the information on potential risks constitute the prerequisites for sound judgment of incoming messages and stopping hoaxes.

Overview of learning objectives and competences

In LO_The basic starting point_01 you will learn
which properties of nanomaterials can, in addition to indisputable benefits, represent a potential risk for human health.

In LO_Contact of people with nanostructures_02 you will receive
information on nanotechnology in the nature, on conscious as well as unconscious creation of nano solutions by people, and on the existing release of manmade nanoparticles into the environment.

In LO_Protecting people from dangerous nanoproducts_03 you will learn the basics of…
danger for humans associated with nanoparticles of natural origin as well as those produced by human work and use of various products. At the same time, you will gain insight into the development of safe nanotechnology solutions and find out what to focus on while receiving information related to safety of nanotechnology to be able to assess its correctness.

Learning objectives	**Fine objectives**
LO_ The basic starting point_01: you will learn which properties of nanomaterials can, in addition to indisputable benefits, represent a potential risk for human health.	FO_ **What are the potential dangers of nanomaterials**_01_01: you can learn why physicochemical properties of solid substances change in nanoscale and how nanoparticle size of 1 - 100 nanometers behaves in interactions with the cells of the human body.
LO_ Contact of people with nanostructures_02: you will receive information on nanotechnology in the nature, on conscious as well as unconscious creation of nano solutions by people, and on the existing release of manmade nanoparticles into the environment.	FO_**Where nanotechnological objects occur in nature**_02_01: you will understand the creation of nanoparticles in the nature, whether as a beneficial solution, or as a seemingly non-functional or harmful product. FO_**How intentional and unconscious we create nanoproducts**_02_02: you will learn how humans have unknowingly created nanosolutions in the past and where we are consciously heading in this area today. FO_**What dangerous nanostructures we release into the environment**_02_03: you will get an overview of how nanoparticles are released into the environment as a result of human activities.

LO_ Protecting people from dangerous nanoproducts_03: you will learn the basics of… danger for humans associated with nanoparticles of natural origin as well as those produced by human work and use of various products. At the same time, you will gain insight into the development of safe nanotechnology solutions and find out what to focus on while receiving information related to safety of nanotechnology to be able to assess its correctness.	FO_**How we can protect ourselves from unwanted nanostructures in the workplace**_03_01: you can review which circumstances represent the greatest health risk for personnel FO_**Why cooperation with nanotoxicologists is needed in the development of new nanotechnology products**_03_02: you can reason why it is desirable to assess the safety of a nanotechnology procedure or product during its development FO_ **How to prevent potential dangers from nanotechnology solutions**_03_03: you can learn how to approach the development of a nano product to make its safe throughout its lifecycle FO_ **How to safely handle nanomaterials**_03_04: you can learn how physicochemical properties of materials change in nanoscale, what dangers this represents and how to tackle such dangers FO_ **How to proceed in detecting possible hoaxes related to nanotechnologies**_03_05: you can learn how to use scientific knowledge to expose manipulative conspiratorial practices and to set straight any nonsensical claims.

1. The basic starting point

What are the potential dangers of nanomaterials

Nanotechnologists work with matter of 1 nm to 999 nm in size. However, in recent years, the concept of nanomaterial has been used to denote only a tenth of the nanoscale dimension - from 1 nm to 100 nm. One of the principal reasons why the dimension of 1 nm to 100 nm was singled out for the definition of nanomaterials was the safety concern. Particles in the range of one to tens of nanometers can penetrate cells of the human body. Particles of hundreds of nanometers in size lack such ability, i.e. they cannot penetrate through the cell wall. Therefore, a lot of directives, decrees, and regulations stipulating restrictions and enhanced control of nanomaterials are, as a precautionary principle, focused on the 1 nm to 100 nm dimension.

The simplification based on the fact that physicochemical properties of solid substances are not the same inside the material and on its surface. When particles of a material are reduced below 100 nm, the physicochemical properties of the surface prevail over the properties of the material and the particle starts to behave as if it was composed of the surface in its entirety. Particularly important are the intermolecular and other forces that act on dimensions in the range of tens of nanometers. Thus, nanomaterials can have different proprieties than the same material at a larger scale such as the microscale.

Definition
Nanomaterials On 18 October 2011, the European Commission issued the Recommendation 2011/696/EU on the definition of nanomaterial. According to the adopted definition, "a nanomaterial means a natural, incidental or manufactured material containing particles, in an unbound state or as an aggregate or as an agglomerate and where, for 50 % or more of the particles in the number size distribution, one or more external dimensions is in the size range 1 nm-100."

3. Save knowledge

Summary

You reached the end of the content unit about **Main directions of the use of nanotechnologies in contemporary medicine.** As there was a lot to learn, please receive a quick repetition of the most important things you learned about this topic:

One of the principal reasons why the dimension of 1 nm to 100 nm was singled out for the definition of nanomaterials was the safety concern. Particles in the range of one to tens of nanometers can penetrate cells of the human body.

The physicochemical properties of solid substances are not the same inside the material and on its surface. When particles of a material are reduced below 100 nm, the physicochemical properties of the surface prevail over the properties of the material and the particle starts to behave as if it was composed of the surface in its entirety. Thus, nanomaterials can have different proprieties than the same material at a larger scale such as the microscale.

The topic

The principals of the contact of people with nanostructures

Where nanotechnological objects occur in nature

Nature creates a myriad of nanostructures, either intentionally, or unintentionally. The functionality of some of them can be commonly observed. For example, most plants get wet in contact with water, while droplets of water run down the surface of lotus leaves and blossom without adhering to the lotus. It is due to the water-repellent (hydrophobic) nanostructure of the surface of the lotus. By creating such nanostructure, nature creates more favourable conditions for living organisms, enabling them to survive and continue in successful evolution.

Certain nanostructures are created in nature unintentionally. For example, at any given moment on Earth, there is a fire, volcanic eruption and other combustion processes releasing nanoparticles into the atmosphere. All living creatures, including humans, inhale such nanoparticles or absorb them otherwise. Our metabolism and immune system can usually handle such nanoparticles, processing most of them and eliminating them from the body. However, if the quantity of the nanoparticles entering the body exceeds the capacity of our metabolism and immune system, the consequences can be fatal.

Definition
The lotus effect Despite permanent exposure to dust, dirt, rain and other phenomena, leaves and blossoms of lotus remain clean and dry. The secret of the lotus blossom hides in its surface. Tiny bulges of just a few nanometers in height cover the surface of the leaf, protecting it from sedimentation of dirt and dousing with liquids. This ability of the lotus keeps its leaves constantly clean and dry, even in rain. Scientists used this particular nanotechnology to simulate the effect, creating surfaces that repel water, do not absorb liquids, and have self-cleaning properties.

Example
Paws of the gecko can hold the animal reliably on the glass ceiling or wall of the terrarium. The adhesive segments on the bottom of the paws use molecular interaction (the so-called Van der Waals force) between their fine keratin hairs of 30 to 130 nanometers in length and the smooth surface the gecko crawls on. This method of attachment requires the ends of the hairs to “wedge” into the tiniest irregularities of the surface. They must approach the atoms of the surface at a distance at which the Van der Waals bond is created. Natures has thus created a remarkable nano solution.

How intentional and unconscious we create nanoproducts

People have used nano solutions in the past without calling them that. Gold and silver nanoparticles were used in Persia already in 10th century B.C. to produce ceramic glittering glazes of beautiful colours. When the first glass workers added a small coin of gold into the melt, dying the glass red, they had no idea that they became nanotechnologists. Their discovery that molten gold turns yellow to red in nanoscale was a sheer coincidence.

We use nano products in everyday life, e.g. in toothpaste, sunscreen, deodorant, shampoo, beauty skin care and antibacterial products, etc. The use of nanotechnology and nanomaterials is very broad, such materials are used in many applications in many areas like

- electronics (memory media, spintronics, bioelectronics, quantum electronics),
- healthcare (targeted drug delivery, artificial joints, valves, tissue replacement, disinfectant solutions of next generation, analysers, protective face masks),

- engineering (super hard low-friction surfaces, self-cleaning scratch resistant materials, machining tools),
- construction (new insulating materials, self-cleaning façade coating, anti-adhesion tiles),
- chemical industry (nanotubes, nanocomposites, selective catalysis, aerogels),
- textile industry (non-shrinking, hydrophobic and non-staining fabrics),
- electric engineering (high capacity recording media, photographic materials, fuel cells),
- optics (optical filters, photopic crystals and photopic fibres, integrated optics),
- automotive industry (non-wettable surfaces, windscreen filters),
- aerospace industry (catalysers, durable satellite surface materials),
- defence industry (nano sensors, structural elements of space shuttles),
- environment (removal of contaminants, biodegrading, food labelling), etc.

Example
Not many car owners realise that their vehicle is carried on the road by nano products – tyres. The tyre composition includes soot, i.e. nanoparticles produced by combustion of oil products. Soot as a filler constitutes about 30% of tyres. Soot adds rigidity and hardness to tyres and makes them resistant to wear and heat. As regards safety, it should be noted that as the vehicle moves down the road or in the terrain, micro- and nanoparticles are released into the environment.

What dangerous nanostructures we release into the environment

People unknowingly produce nanoparticles by lighting a candle, a cigarette, fire in the fireplace or stove. However, a lot more dangerous is the effect of chemical substances bound to fine dust particles emitted into the air by industrial operations and the nanoparticles in combustion engine exhausts. Rubbing of a tyre against asphalt or other surface abrades and releases a large number of ultrafine particles into the environment. It is very important to reduce the undesirable concentration of such particles in our environment.

People are in contact with nanoparticles of different concentrations in their everyday life. They can experience increased concentration of nanoparticles at certain locations (industrial areas of cities) or during certain activities (sport shooting, smoking, fireworks), or while working at industrial facilities.

Targeted production of nanoparticles is currently relatively limited, but already now we need to do everything to ensure that industrially produced nanoparticles perform their function only where desired and do not enter spaces where they are not intended. In general, however, as long as nanomaterials are firmly anchored into larger units and not released uncontrollably into the environment, they can threaten neither the environment, not human health in any unknown way.

5. Save knowledge

Summary

You reached the end of the content unit about nanosafety. As there was a lot to learn, please receive a quick repetition of the most important things you learned about this topic:

Nature creates a myriad of nanostructures, either intentionally, or unintentionally. The functionality of some of them can be commonly observed. By creating such nanostructure, nature creates more favourable conditions for living organisms, enabling them to survive and continue in successful evolution.

Certain nanostructures are created in nature unintentionally. For example, at any given moment on Earth, there is a fire, volcanic eruption and other combustion processes releasing tons of nanoparticles into the atmosphere.

All living creatures, including humans, inhale such nanoparticles or absorb them otherwise. Our metabolism and immune system can usually handle such nanoparticles, processing most of them and eliminating them from the body. However, if the quantity of the nanoparticles entering the body exceeds the capacity of our metabolism and immune system, the consequences can be fatal.

Targeted production of nanoparticles is currently relatively limited, but already now we need to do everything to ensure that industrially produced nanoparticles perform their function only where desired and do not enter spaces where they are not intended.

The principals of the protecting people from dangerous nanoproducts

How we can protect ourselves from unwanted nanostructures in the workplace

To protect workers from hazardous nanoparticles, it is necessary to be aware of the circumstances under which such particles are created. Even in areas seemingly unrelated to nanotechnology. It is undisputed that nanoparticles are produced e.g. by the combustion process. For example, when a welder is welding, he should be wearing not only a face shield and gloves to protect himself from sparks than can burn him and damage his eyesight, but he should also protect his respiratory system as he is inhaling large quantities of nanoparticles produced by welding throughout his working time. Similarly, quantities of nanoparticles inhaled by roadwork personnel laying down asphalt surface without respirators, etc. should also be reviewed. People still inhale nanoparticles at many worksites without employers taking this into consideration and creating suitable conditions to protect their employees against pollution which, in the long-term, puts employee health at risk.

If nanotechnology companies produce nanoparticles for further processing, personnel handling the nanoparticles needs to be protected by personal protective equipment. The most important in this area is the protection of mucous membranes, in particular the respiratory system and the eyes. This requires that workers be equipped with efficient respirators and goggles that fit snugly against the employee's face skin. Technological facilities working with nanomaterials also try to protect their personnel from potential risks by deploying ventilation systems, air filtering system, etc.

Cleanliness of the working environment is usually best ensured in production facilities making products with nano surface treatment. If any dirt were to get on the nano layer of the product, the functionality of such product would be hindered irreversibly. Clean production environment thus protects not only the product, but also the operating personnel.

Why cooperation with nanotoxicologists is needed in the development of new nanotechnology products

Safety of new nano products must be verified already during the development, i.e. long before the launch of mass production. The product needs to comply not only with the existing standards and regulations which often do not include nano solutions in their concepts, but also with regard to the possible penetration of the nanomaterial into the human body or the environment. The potential toxicity of nanoparticles developed for a specific application must be known before use in real life.

Academic institutions have available the means to verify the safety of new nanomaterials and to objectively determine the mechanisms of any toxic effects of mass-produced nanoparticles as well as their potential impact on human health. It is also necessary to take into consideration what happens with the nanomaterials throughout their lifecycle, whether and in what concentrations they could represent a threat to the human health.

Definition
Nanotoxicology Nanotoxicology is a branch of toxicology concerned with the study of the toxicity of nanomaterials, which can be divided into those derived from combustion processes (like diesel soot), manufacturing processes (such as spray drying or grinding) and naturally occurring processes (such as volcanic eruptions or atmospheric reactions).

How to prevent potential dangers from nanotechnology solutions

In order to make use of the unique properties of materials in nanoscale while avoiding the undesirable penetration of nanoparticles into cells and dispersion in the environment, it is necessary to develop a suitable binder and other bends between the particles and materials in macroscale. For example, if we wish to exploit the ability of nano silver to prevent bacterial growth and at the same time, we do not want the nanoparticles to reach other places than those where they are medically beneficial, we must bind them inseparably to the dressing textiles constituting the carrier. For this purpose, we use, inter alia, inseparable bonds in polymers as well as other solutions of similar effect.

The Covid-19 pandemic brought up questions about how nature will handle nanomembranes in masks and respirators in the context of the pandemic. Pursuant to the European legislation, all such medical equipment is to be burned in incineration facilities. However, nanotechnologists asked themselves whether all users of nano masks and nano respirators actually behave responsibly and in compliance with the law. The irresponsibility of some consumers leads nano producers to promoting the trend of using biodegradable materials in production of organic nanofibers suitable for nanomembranes. Such approach should be adopted in production of virtually any disposable products.

Definition
Biodegradability Biodegradation is the process of decomposition of a substance in nature involving natural biological processes. Virtually any material is biodegradable, the difference is in the time required for decomposition of a substance in the natural environment. The highest requirements for quick decomposition are associated with biodegradability in a human body.

How to safely handle nanomaterials

Just as we have learned to use fire to our benefit in the past, we must work even with highly reactive nanoparticles with the same level of caution and safety. Only thus can we use their unique properties in the right way. For every nanomaterial, we need to examine how its physicochemical properties change in nanoscale, what the risks are and how they can be eliminated or mitigated.

Example
Contaminants like poisons or oils can be settling in the ground for years like an environmental timebomb. Thanks to new technologies, some hidden threats can be eliminated successfully. Such cleaning process is called remediation of environmental burden. It also uses nano-iron. When a piece of iron oxidises in the macroworld, the observer perceives the process as rusting. It takes weeks or months before a common piece of iron gets rusty. Nano iron oxidises long before it hits the ground when dropped from the height of one meter. While moving, virtually the entire surface of iron nanoparticles that gets in contact with air actually reacts with the air. When exposed to air, nano iron burns so quickly that the oxidation process appears as an explosion. Nano iron in suspension for breaks down the water molecule. This produces hydrogen and if not handled properly, problems with transport and storage of nano iron could arise. Therefore, nano iron should only be handled by duly trained specialists. Having reacted with nano iron, toxic substances harmful to humans or other living organisms become non-toxic. Particularly with organic substances, nano iron usually reacts in such a way that the substance is transformed into another non-toxic substance. Nano iron is also capable of degrading toxic metal-based contaminants. Metal, even heavy metal, will always be metal, only its form will change. In the ground, metal is usually water soluble. So it can reach humans, posing a threat to them. Nano iron can convert such metal into a form that is no longer water soluble and thus it does not pose a threat anymore. Working with nano iron, it is necessary to predict and subsequently monitor the entire process of reaction with toxic substances. We need to know in advance how nano iron will react with all of the

substance it will react with when cleaning the contaminated sites, how large the newly formed particles will be and what their further evolution will be.

How to proceed in detecting possible hoaxes related to nanotechnologies

One of the frequent improprieties that the internet is riddled with, is spreading of alarming and harmful chain mails called hoaxes. These include fabricated alerts and rumours. The hoax tries to convince by its artificial importance, quoting alerts by trustworthy sources, or on the other hand, it conveys a 'leaked' information. Hoaxes can also be defined as messages containing inaccurate, misleading information, purposedly modified half-truths or a mix of half-truths and lies. In addition to that, a hoax is usually concluded by a prompt to the recipient to spread it further.

Nanotechnology and products using nano solutions are more and more often a target of hoaxes spread via the internet. People cannot imagine the nanoscale. Authors of hoaxes thus exploit the natural fear of the unknown. They often combine true information with utter nonsense. In order to debunk a hoax, the reader will need more than just the knowledge acquired at the primary or secondary school. He or she needs to look up sources. Hoaxes often refer to non-existent studies or non-existent quotes by actual or fabricated authorities. If the reader wants to find out the actual state of affairs, he or she should seek for the very sources available on trustworthy websites. They should also carefully assess the meaning of the words. If an authority claims that they are concerned about something, they should also state whether such concern is backed up by a relevant scientific study, etc.

Example

In the early months of 2021, a video went viral worldwide where an American TV and film producer and the head of an anti-vax group Informed Consent Action Network Del Matthew Bigtree and an investigative journalist Jeffrey Jaxen speak of a study called: “The Need for an Evaluation of Inhalation of Micro(Nano)plastic Particles from Masks, Respirators and Homemade Masks during the Covid-19 Pandemic.” They show a photograph of microfibers with captured, particles and comment: “We see micro and nano level fibres, fragments, particles everywhere. According to the study, they are just loosely bonded to the structural fibres of the product. Blue arrows show micro fibres. Red arrows indicate particles and fragments on sub-micro and nano level. You see that they are everywhere. As the study says, they are just loosely bonded. Why is this a problem? In 2012, the University of Edinburgh in the UK referred to a study they did.” And the quote Professor of Respiratory Toxicology Ken Donaldson: “There have been concerns that new types of nanofibers produced by the nanotechnology industry could pose a risk as their shape is similar to that of asbestos.”

If the user wanted to verify this, they could search for the study on the internet using Google. If they succeeded, they should see where it was published. If such a study was published on the website of the University of Edinburgh, it would sure be worth reading. If Professor Ken Donaldson has ever said that “there have been concerns that new types of nanofibers produced by the nanotechnology industry could pose a risk as their shape is similar to that of asbestos”, surely he also said whether the concerns have been proven justified, or false.

The overwhelming majority of non-woven textiles used in production of face masks and respirators are made of the so-called continuous fibres which are also interwoven. Images from a scanning electron microscope prove that the particles were captured by the respirator, not that they are released by the respirator. There are huge quantities of dust and other particles in the air, including those commonly produced by combustion engines. Respirators and masks, particularly those made of nanofibers, commonly capture such particles due to the electrical forces present. The comparison with asbestos is completely misguided, as asbestos is one of the inorganic fibres, while respirators and masks are made of safe polymer fibres.

If the user cut or tore the nanofiber face mask to pieces and exposed the nanofiber membrane, it is virtually impossible that they could extract or release a single nanofiber from the nano structure. Even in lab environment, a nano-knife or other apparatus has not yet been constructed that could remove a nanofiber from the nanofiber membrane and cut it into nanoparticles. The length of a single nanofiber is at least on the order of hundreds of micrometres to units of millimetres. Every nanofiber crosses with other nanofibers at hundreds or even more places along its length. At these points, a friction force exerted between the nanofibers does not allow for easy separation of single nanofibers from the structure. A mechanical force can lead to tearing of the nanofiber layer and separation of a cluster of nanofibers. However, such clusters resemble a wrinkle and they are tens to hundreds of microns in size. Such wrinkles have the character of common dust. When inhaled, they would be captured by the ciliated epithelium in the nasal cavity. The epithelial cells secrete mucus which traps various dust particles. The ciliated cells move the mucus into the nasopharynx, from where it travels to the digestive tract. Through the digestive tract, people then expel the impurities from the body. The size of the mucus produced does not allow it to pass through the cell wall in the digestive tract or the lining of the respiratory tract. Medical nano face masks compliant with the European standard EN 14683 are also tested for cytotoxicity and skin tolerance as a part of the certification process. The European certificate thus confirms their health safety.

7. Save knowledge

Summary

You reached the end of the content unit about nanotoxicology. As there was a lot to learn, please receive a quick repetition of the most important things you learned about this topic:

How we can protect ourselves from unwanted nanostructures in the workplace

To protect workers from hazardous nanoparticles, it is necessary to be aware of the circumstances under which such particles are created. Even in areas seemingly unrelated to nanotechnology. People still inhale nanoparticles at many worksites without employers taking this into consideration and creating suitable conditions to protect their employees against pollution which, in the long-term, puts employee health at risk.

If nanotechnology companies produce nanoparticles for further processing, personnel handling the nanoparticles needs to be protected by personal protective equipment. The most important in this area is the protection of mucous membranes, in particular the respiratory system and the eyes.

Nanotechnology is considered to be a key enabling technology by the European Commission. It is considered to be an enabling technology, which is relevant for many sectors, such as chemicals, consumer products, health, energy, and the environment. As a consequence, the EU regulatory framework covers nanomaterials and potential risks associated with them. Safety of new nano products must be verified already during the development, i.e. long before the launch of mass production. The product needs to comply not only with the existing standards and regulations which often do not include nano solutions in their concepts, but also with regard to the possible penetration of the nanomaterial into the human body or the environment. It is also necessary to take into consideration what happens with the nanomaterials throughout their lifecycle, whether and in what concentrations they could represent a threat to the human health.

Just as we have learned to use fire to our benefit in the past, we must work even with highly reactive nanoparticles with the same level of caution and safety. Only thus can we use their unique properties in the right way. For every nanomaterial, we need to examine how its physicochemical properties change in nanoscale, what the risks are and how they can be eliminated or mitigated.

Nanotechnology is more and more often a target of hoaxes spread via the internet. Authors of hoaxes exploit the natural fear of the unknown. In order to debunk a hoax, the reader will need more than just the knowledge acquired at the primary or secondary school. He or she needs to look up sources. Hoaxes often refer to non-existent studies or non-existent quotes by actual or fabricated authorities. If the reader wants to find out the actual state of affairs, he or she should seek for the very sources available on trustworthy websites. They should also carefully assess the meaning of the words. If an authority claims that they are concerned about something, they should also state whether such concern is backed up by a relevant scientific study, etc.