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Research Article

THE INVESTIGATION OF NANOMATERIALS IN TERM OF HUMAN HEALTH

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ABSTRACT

Nanotechnology is one of today's most popular research areas. The reason for this is that, thanks to this technology, production can be much better and much smaller. Investments in this technology increase each year and it is predicted that the increase will continue. The fact that more nanomaterials are in our lives has become a necessity for further research into this technology. Many studies have been done on nanomaterials for a long time, but most of them are those that highlight the positive aspects of nanomaterials on humans. Until a few years ago, studies on the negative effects of nanomaterials on living things, especially humans, are insufficient. In recent years, increasing use of nanomaterials necessitated the examination of the effect on human health. As a result of research, some nanomaterials have been determined to have negative effects on human health. These materials are especially risky for workers during production. People and institutions working with nanomaterials need to take some security measures. These measures should be determined according to the properties of nanomaterials. Taking the necessary precautions reduces the possibility of exposure. The negative effects of nanomaterials on human health are still being investigated. However, thanks to its superior features, its popularity is rapidly increasing and it is expected to continue to increase.

Keywords: *Nanotechnology, Nanomaterials, Occupational Health and Safety, Ergonomics*

1. INTRODUCTION

Nanotechnology; it is the technology where the substances are examined by going down to 1-100 nm dimensions and the information obtained as a result of these investigations are used for applications in various fields (Ramsden, 2011; Allhoff *et al.*, 2010). Nanotechnology has an impact on human life on a large scale. This change is clearly seen through many years of work. For example; mobile phones used today have been thought many years ago. However, due to technological deficiencies at that time, if they were to be produced, their size would have reached a building size (Ramden, 2011). The effect of technology on the dimensions of products can be clearly understood by this example. This is the most remarkable innovation of nanotechnology.

Nanotechnology addresses many different areas and continues to innovate in areas. Solar creams that do not emit ultraviolet light through nanotechnology, lighter and more robust tennis rackets, self-cleaning glass production (Ramden, 2011), along with some other technologies (ultrasonic, HC) to be successful in removing waste water (Beth *et al.*, 2018), increasing shelf life of foods by using nanomaterials in the food industry (Gokkur *et al.*, 2012). Such developments add quality to our lives but do not have the effect of changing our lives completely. Intensive studies are being carried out on developments that can be considered a revolution in nanotechnology. Wars can cause great changes on earth. Countries are investing in a lot of money to be successful in the wars which are extremely important for them. Nanotechnology can be very effective in the military because it provides more efficient and light products. In 2002, the United States established a research center called the Military Institute of Nanotechnology at the Massachusetts Institute of technology. (Allhoff *et al.*, 2010) the task of this research center is to make innovations that will increase the productivity of the soldiers at the time of the operation. A soldier weighs 45. it carries equipment and moving with this weight for a long time can cause soldiers to get tired early and decrease their productivity. Equipment produced using nanotechnology is much lighter. Only for this reason nanotechnology can be used for military purposes. But nanotechnology will not only bring lightweight on soldiers, it will have the potential to do innovations that will affect the course of the war. Superior products, for example, such as self-administered bullets, nano-sized robots that can disrupt electrical or chemical systems in a region, can play a major role in determining the end of the war (Allhoff *et al.*, 2010).

Nanotechnology is clearly known to bring benefits and innovations in many areas. However, the use of nanomaterials involves some risks and problems. In this study, the risks and precautions to be taken in the use of nanomaterials were investigated.

2. THE EFFECTS OF NANOMATERIALS ON HUMAN HEALTH

With the development of technology, new materials have been produced and used. Thanks to these materials, many new and superior products can be produced. However, changing materials can also cause some health problems. Besides many superior properties of

nanomaterials, it can cause serious health problems especially if precautions are not taken (Buzea *et al.*, 2007; Esmaeillou *et al.*, 2012; Geraci *et al.*, 2015; Kuhlbusch *et al.*, 2018; Li *et al.*, 2018; Liu *et al.*, 2012; Mala *et al.*, 2018; Naqvi *et al.*, 2018; Pietroiusti *et al.*, 2018; Schulte *et al.*, 2008; Zalk *et al.*, 2009).

As a result of the research, there are more than 1600 Nano-active products today. By 2020, 6 million workers will be exposed to the ever-increasing nanomaterials (Li *et al.*, 2018). Fig. 1. shows the changes in nanotechnology investments over the years. As shown in Fig. 1., the investment in nanotechnology is expected to increase over the years and will continue to increase. For this reason, as time goes on, the risks of nanomaterials on human health will increase.

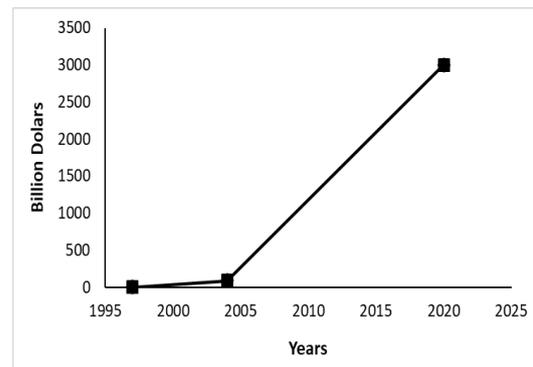


Fig. 1. Changes in Investments for Nanotechnology by Years (Esmaeillou *et al.*, 2012).

Studies to examine the effects of nanomaterials on human health are basically two types; in vitro (in laboratory) and in vivo (in living organisms). Studies conducted in vitro laboratory environment. The advantage is that getting quick results and low cost. It is also an ethically more appropriate method because there are no applications on living things. Some experiments that can be carried out include the polyphase test, the apoptosis test, the necrosis test, the oxidative stress test and DNA damage tests (Kumar *et al.*, 2017). In vivo is usually done on animals such as rats or mice. Nanoparticles in dead or alive organisms are determined by radio labels. The in vivo method also determines the level of toxicity of the nanoparticle by examining the organisms exposed to the nanoparticles. Histopathology of living organs, cells or tissues is used after exposure (Kumar *et al.*, 2017).

As a result of researches, nano-sized particles are observed to pose more risk to human health than macro-sized particles. Nano-sized particles damage the lungs through respiration. At the same time, these particles can easily penetrate the circulatory system and reach the nervous system and the brain (Ozdemir *et al.*, 2015; Unver, 2016). The effect of nanoparticles on human health has been shown to depend on particle size. For example, if the size of particles taken from the lungs is less than 100 Nm, they can reach the alveoli in our blood vessels (Köksal *et al.*, 2014). As mentioned, the particle size has a significant impact on human health. According to particle size, the accumulation areas in the human body (especially the respiratory system) are also different. Fig. 2. shows the accumulation zones of materials in the respiratory system according to particle size.

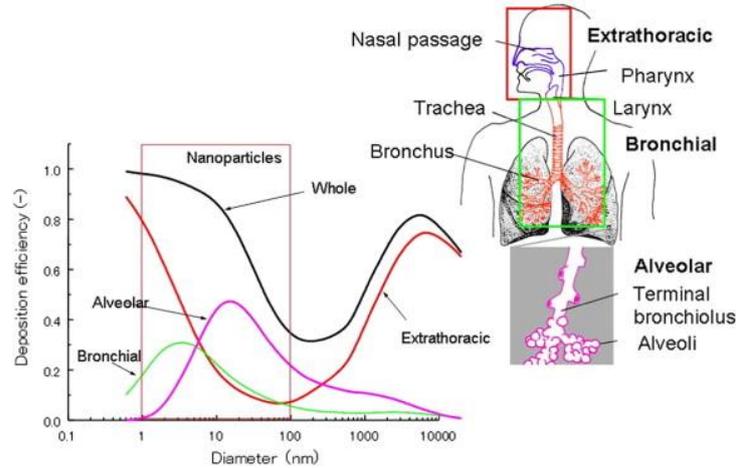


Fig. 2. Accumulation zones in respiratory system according to particle size (Geraci *et al.*, 2015)

Many animals and plants were used to investigate the damage of nanoparticles. For example, the effect of titanium dioxide nanoparticles on water flea, the effect of silver nanoparticles on water lentils, the effect of zinc oxide nanoparticles on mussels, the effect of zinc oxide nanoparticles on offspring carp, as a result of many researches have shown that nanoparticles pose a risk for plants and animals. In light of these studies, the first study to determine the negative effects of nanoparticles on human health was carried out in 2009 (Özdemir, 2015).

In cases where nanoparticles are small enough, they can easily enter the cell and bind to DNA and cause some genetic damage. Especially silver, aluminum oxide, titanium dioxide, iron oxide, zinc oxide, such as nanoparticles can lead to DNA damage has been determined (Santos *et al.*, 2013; Collins *et al.*, 2017; Dogan *et al.*, 2018; Esmaeillou *et al.*, 2012, Akyol *et al.*, 2018; Sekeroglu, 2013).

2.1. Exposure Routes of Nanomaterials

Nanoparticles can enter the human body and cause some health problems when certain conditions are met. Nanoparticles can enter the human body through respiration, through skin and through digestion. Nanomaterials, which are extremely small and light, enter the human body by breathing the most. The nanoparticles that enter our body by inhalation can reach other organs by the circulatory system except the lung and brain. Nanoparticles entering the body through the digestive tract can reach the stomach and intestinal tract and from there with blood to other organs of the body. If the nanoparticles enter the body via the skin, they can be mixed into the lymph system (Unver, 2016). The ways in which nanoparticles enter the human body are shown in Fig. 3. As can be seen in Fig. 3., the nanoparticles can spread through the body after entering certain ways into the human body.

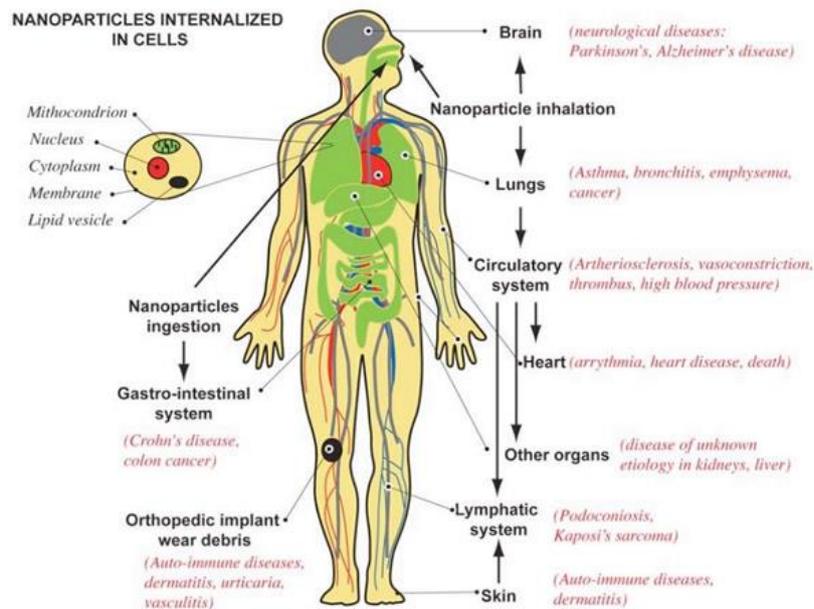


Fig. 3. Schematic representation of the ways nanoparticles enter the human body (Buzea *et al.*, 2007)

2.2. Determination of Exposure

The popularity of nanomaterials is increasing due to many extraordinary properties. As shown in Fig. 1., investments have increased from year to year and are expected to increase further. In addition to the many advantages of nanomaterials, it is known that they have characteristics that may pose a risk to humans and the environment. People interact intensively during the use and production of these materials. In particular, people who work in the production of nanomaterials are at greater risk of exposure. Nanomaterials are also important in the size, amount and in which way they enter the human body. Knowing the nanoparticle size and amount is important for the precautions to be taken and the procedures to be applied after exposure. For this reason, many devices have been produced to determine the exposure risks of people in working environments. These devices can determine the amount and size of nanoparticles in the environment (Naqvi *et al.*, 2018; Pietroiusti *et al.*, 2018). Fig. 4. shows the CPC device;



Fig. 4. CPC device (Babaarslan, 2014)

The CPC (Condensation Particle Counter) device serves to determine the number of particles. The operating principle of the device is based on the counting of droplets formed by the concentration of alcohol vapor and the optical detector. The device capacity is 1-1000 nm and is better than other similar devices if operated in single particle mode (Kuhlbusch *et al.*, 2018). Fig. 5. shows the mini-disk device. The main task of this device determines the amount of nanoparticles. It also measures the average diameter and surface areas of nanoparticles. These features differ from CPC. It is a simple and convenient device that is easy to use and does not work with an extra resource.



Fig. 5. CPC device (Babaarslan,2014)

The OPC (optical Particle counter) shown in Fig.6. is a different device used to determine the number of particles. OPC measuring range 200nm - 20µm (Kuhlbusch *et al.*, 2018).



Fig. 6 . OPC device (Babaarslan, 2014)

Fig. 7 shows SMPs (Scanning mobility Particle sizer). The task of the SMPs device is to determine the size distribution of particles. Although many devices are available in this function, it is the most widely used SMPs device (Babaarslan, 2014). SMPs device capacity is 1-1000nm. Although such devices have been developed for years, there are still some deficiencies and studies are continuing (Kuhlbusch *et al.*, 2018). The disadvantage of the SMPs device is that it is slow. It also performs different scans for each different dimension (Babaarslan, 2014).



Fig. 7. SMPs device(Babaarslan,2014)

Fig. 8. shows the SEM (Scanning Electron microscopy). SEM is based mainly on the study of the interaction of electrons from an electron source with the material to be studied. Some electrons come out of interaction with the material to be studied. These are secondary electrons and backscatter electrons. The secondary electron is the result of the collision of the incoming electron with the material to be studied. This electron occurs at a depth of about 10 nm. The secondary electrons that occur are collected and applied to obtain the surface image. Another type of electron is the scattering electron, which comes more deeply (at about 300nm depth) than the secondary electron. It also has higher energy than the secondary electrons. In addition to these, X rays occur as a result of another interaction between the electron and the material. X rays contain high energy and influence from the surface of the material to 1000 nm depth (Babaarslan, 2014). SEM devices achieve very precise results, and these results depend on the imaging capacity of the device. In general, their capacity is 0.1 nm-1 mm (Kuhlbusch *et al.*, 2018).



Fig. 8. SEM device (Reddy *et al.*, 2017)

3. RISK ASSESSMENT

Persons working with nanomaterials are at risk and should be decided how to take measures. Devices such as CPC, OPC, SMPS, SEM are used to determine the size and quantity of nanoparticles in the environment. Although these devices provide information about the size and quantity of nanoparticles, they do not provide information about the sources and chemical composition of nanoparticles (Pietrojusti *et al.*, 2018). Therefore, the presence of devices does not eliminate the risk in the environment while providing information about measures to be taken.

To assess the risk of the working environment, measurement can be carried out with the devices used to determine the exposure of workers in respiratory zones and in the environment. When the two measurements are compared, it can be interpreted that the workers are exposed to nanoparticles if the concentration of nanoparticles in the respiratory zone is greater (Pietrojusti *et al.*, 2018).

As result of the processes, information about the nanoparticles is obtained. Thus, the risk level and exposure are determined. However, in some cases, sufficient information cannot be obtained about the characteristics of nanoparticles in the environment. In these cases, other methods must be applied. Although there are multiple methods, the most reliable is the control banding method (Babaarslan, 2014). In this method, some properties are determined as the force parameter and some coefficients are assigned to these properties. In addition to these parameters, some probability factors have been determined and coefficients have been assigned to these parameters. The risk matrix is formed by collecting the coefficients of these two different parameters. The risk level is determined by means of charts from this risk matrix (the second parameter value corresponding to the first parameter is read) (Zalk *et al.*, 2009).

There are some important problems when making a risk assessment. For example, there are some situations that need to be taken into account in the control banding method. This is a matrix method used in this method. In matrix methods, some values are assigned in case an event or situation occurs. Therefore, the degree of violence is determined as a result of these acceptances. However, there are some uncertainties when determining the degree of intensity. In these cases, what to do should be considered and included in the evaluation.

Calculations should be made based on the worst case that may occur in unknown uncertainties. So the Unknown should be considered the highest danger.

The risk assessment parameters in the control layers method are intensity and probability (Unver, 2016). Density factor score is mostly (70%) in nanomaterials and the rest is the main material. Intensity factors; particle shape of nanomaterials, surface chemistry of nanomaterials, solubility of nanomaterials, particle diameter of nanomaterials, the cancer-causing condition of the nanomaterials, effect of nanomaterials on reproduction system, effect of nanomaterials on dermal, the risk status of the main material (toxicity), the cancer-causing condition of the main material, the negative effect of the main material on the reproductive system, the muatajenlik of the main material, the dermal effect of the main material, the negative effect of the main material on asthma (causing asthma or worsening the situation) is determined. Another parameter the probability parameter, is the amount of nanomaterials used during the process (a suitable estimation should be obtained if couldn't a precise result is obtained), the working environment is dusty, foggy or in a condition that makes breathing difficult, the number of people working in the environment that is thought to be exposed, working time factors.

3.1. Determination and implementation of measures

Considering the characteristics of nanomaterials, the precautions to be taken against the risks that may occur should differ according to other materials. During the production of nanomaterials, significant problems can occur in the aspect of employees. The procedures to be applied as a result of the risk assessments and measures to be taken are determined. Before making a risk assessment in a place where nanomaterials are produced, a pre-hazard analysis should be established to make the risk assessment more healthy (Unver, 2016). In the context of pre-hazard analysis, an analysis should be made on the subjects such as materials to be used during production, production methods, devices used, workers having sufficient equipment related to the work, whether the company doing the job is sufficient in the work, ventilation system adequacy, material production being made by automatic or direct workers. It will be much easier to make a risk assessment in light of the information obtained as a result of this analysis. Fig. 9. shows the the hierarchy of control measures;

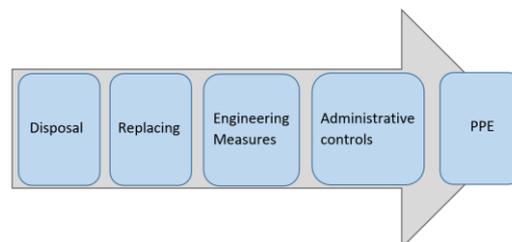


Fig. 9. Control Measures Hierarchy (Unver, 2016)

Control measures vary depending on the type of nanomaterials or process. For this reason, control measures can be examined under five headings. These titles are presented below.

Disposal: Disposal is the first and easiest method. It is to eliminate or reduce the amount of nanomaterials seen at risk. After the production starts, the demolition process can cause some problems. Therefore, it is the first step before the start of the process.

Replacing risky material with another material that is less risky or has no risk at all: The aim of this phase is to change the risky materials to a less risky or non-risky situation. For example, a volatile chemical is replaced with another non-volatile chemical. Thus, it is prevented from mixing the harmful chemical into the air and breathing of the employees.

Improvement of the process: The main purpose of this method with engineering measures is to protect employees from environmental hazards with engineering solutions. Expensive in the short run but cost-effective in the long run (Unver, 2016). For example, in a working environment where ventilation is inadequate, the protection of workers from the air known to be at risk with personal protective equipment (PPE) may seem less costly than the installation of an engineering solution ventilation system. But in the long run, process improvement creates a less costly situation. In addition, it can offer a more effective solution than PPE (Schulte *et al.*, 2008).

Administrative improvements: The aim of this method is to raise awareness about risky situations of employees and managers exposed to nanomaterials. In cases where engineering measures are inadequate, this method is applied. In this method, changes are made to allow workers to be exposed to less (change of working schedule, training and work rotation).

Personal protective equipment use: The use of personal protective equipment (PPE) is at the end of the step of measures that can be taken. In cases where all other methods are inadequate, equipment such as gloves, masks, protective clothing is used to prevent nanoparticles from entering the body (Schulte *et al.*, 2008). The very small nanoparticles can easily enter the human body through the skin. In order to prevent this, polyethylene gloves were found to be more resistant than cotton and polyester gloves (Unver, 2016).

Cotton aprons used in laboratories cannot provide effective protection against nanoparticles. Therefore, it is recommended that workers working with nanomaterials use aprons containing polyethylene instead of these aprons.

The presence of ventilation system is extremely important in the environment where nanomaterials are produced. HEPA filters should be used in ventilation systems. (Pui *et al.*, 2007). In the absence of ventilation system, selection of respiratory protector is important. Respiratory protector should be fully seated on the face first and there should not be any gaps.

4. CONCLUSION

It is known that nanomaterials have many superior properties and their use is increasing rapidly. But as a result of the studies, these materials which have superior properties can also have some effects on human health. Some nanomaterials have toxic properties. For this reason, it is inevitable that people working in production facilities are exposed to nanomaterials that show this toxic property. Very small nanoparticles can easily enter the human body and cause serious disturbances.

Therefore, it is not enough to apply ordinary work safety rules during material production. Environmental conditions and persons with the necessary equipment are important in the Prevention of exposure. Nanomaterials will continue to improve the quality of life with superior features, if the necessary rules are clearly formulated and implemented.

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