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The Risk Assessment of Nano-particles and Investigation of Their Environmental Impact

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***Abstract*—**Nanotechnology is the science of creating, using and manipulating objects which have at least one dimension in range of 0.1 to 100 nanometers. In other words, nanotechnology is reconstructing a substance using its individual atoms and arranging them in a way that is desirable for our purpose.

The main reason that nanotechnology has been attracting attentions is the unique properties that objects show when they are formed at nano-scale. These differing characteristics that nano-scale materials show compared to their nature-existing form is both useful in creating high quality products and dangerous when being in contact with body or spread in environment.

In order to control and lower the risk of such nano-scale particles, the main following three topics should be considered:

1) First of all, these materials would cause long term diseases that may show their effects on body years after being penetrated in human organs and since this science has become recently developed in industrial scale not enough information is available about their hazards on body.

2) The second is that these particles can easily spread out in environment and remain in air, soil or water for very long time, besides their high ability to penetrate body skin and causing new kinds of diseases.

3) The third one is that to protect body and environment against the danger of these particles, the protective barriers must be finer than these small objects and such defenses are hard to accomplish.

This paper will review, discuss and assess the risks that human and environment face as this new science develops at a high rate.

***Keywords*—**Nanotechnology, risk assessment, environment.

I. Introduction

As the science improves rapidly in all different fields all over the world, many benefits are brought to human kind resulting from innovation of creative minds. It has always been like this that each new comer brings new kinds of unknown effects to its environment including human and the nature.

Nanotechnology is not an exception undoubtedly. This science, as will be mentioned, deals with too small particles that are in nano-meter scale and it can be interpreted in this way that these materials have the ability to enter body easily and we predict that they can also penetrate body cells and cause biological adverse effects. So it seems obvious that we should prevent, control and cure diseases and environmental effects that this new science product may cause.

In order to accomplish this wish, it seems essentials to monitor and track the workers' health state who handle and involve duties associated with nano products and conduct laboratory studies to gain information to predict and manage new kinds of problems that the environment will face, to lower the undesirable consequences of using such materials.

Unfortunately, since this technology is in its infantile stage, not enough information is available on how and how much severe nano-products may cause environmental adverse effects, but however by using information and data gathered from effect of smallest particle size available in the science archive, we can estimate the effects of such nano-structures to some extent.

This paper intends to review and discuss the different environmental aspects of using this pioneer science, that will surely play an important role in the future of this world and assess the risks that human will face when manipulating with nano-materials.

II. What Is Nano-technology?

Nano-materials are the substances that have at least one dimension in range of 0.1 to 100 nanometers. Nano-materials and nano-particles can exist in the form of ultra-fine particles, which are nanometer-diameter particles that are not intentionally produced, but are incidental products of processes involving combustion, welding or diesel engines, engineered nano-particles ,which are intentionally produced, nano aerosol, that is a collection of nano-particles suspended in a gas, agglomerate, that is group of particles held together by weak forces, and aggregate, that is a heterogeneous particle in which components are held by strong forces.

Nanotechnology is the science of creating and manipulating of these nano-materials. In other words, nanotechnology introduces the way to rearrange atoms of a substance (each atom is approximately 0.1 nm in diameter) to produce a new property and higher efficiency of the former existing form.

The main reason that environmental effects of nano-particles are of great importance is that when particles are present in nano-size form they exhibit physical, chemical and biological properties that are different from their natural existing form due to several factors.

Research has shown that physiochemical characteristics of particles such as shape, size, surface area, charge, solubility and etc. can influence their effect on biological systems. As mentioned before, not enough information is available on how these differing properties can affect human health; so it makes our work harder to assess and control risks and hazards associated with nano-structure particles.

One reason for not having enough data on this field is that

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the long term diseases that most of nano-particles cause, like other diseases of this kind, need continuous and long term monitoring to find elements and factors that cause them; so for now , in lack of information, we can trust the laboratory works done on rodents exposed to nano-particles and use the results obtained in this way, till human data become available for more precise decision.

III. Nano-materials Hazards

A. Health Concerns

Research shows that physiochemical properties of substances can affect their biological functions [1]. These properties include particle size, shape, surface area, charge and etc. Nano-particles because of having such different properties, gain some new characteristics compared to larger form of the same substance they are formed of. For example, these particles have great potential to enter body when they are in form of aerosols or be in contact with skin. When they are inhaled they may deposit in respiratory system, causing pulmonary inflammation and lung tumors that is not likely to happen for larger particles, or become absorbed in blood and move to other parts of body. But still there are uncertainties about how these ultra-fine particles may introduce occupational health risks since there are many unknown factors that influence the intensity of exposure hazards on human health such as the way nano-particles enter body (exposure routes), their transmission to other organs and biological tribulations that they cause when interacting with body cells.

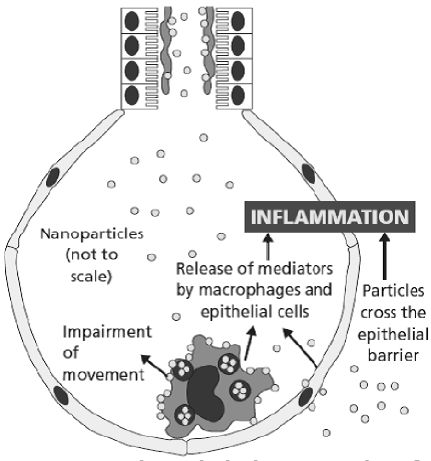

Fig. 1 Nanoparticle uptake by lung macrophage [2]

The risk of health concerns associated with exposure to nano-particles can be dependent on other factors like duration and amount of exposure, the natural toxicity of particle, persistence of nano-particle after entering body and health state of the workers. The toxicity of nano-materials are much more greater than larger particles of same kind and the toxicity may vary according to changes in solubility, shape, surface properties, structure of molecules and so on. For example, studies show that for nano-particles with same properties and equal mass dose the toxicity increases with decrease in particle size due to the surface increase and also it has been found that at the same dose and particle surface area the toxicity of different materials vary with each other, for instance the toxicity of crystalline silica is much greater than TiO2.

In order to have a clearer idea on the health risks nano-particles introduce, we should track these ultrafine objects from the time a worker has a contact with nano-structures up to the moment any sign of a disease appears, so we should first find the ways nano objects may enter our body. Three main routes that are more potent to expose nano-particles are inhalation, ingestion and skin penetration. The main route for nano-particles to enter body is inhalation. Nano-particles after being inhaled are more likely to deposit in respiratory system compared to large particles and amount of deposition is proportional to the particle or agglomerate's diameter. Also breathing from nose or mouth will cause different amount of nano-particles to enter body but it is important to notice that researches show nano-particles can penetrate brain through olfactory nerve situated in nose.

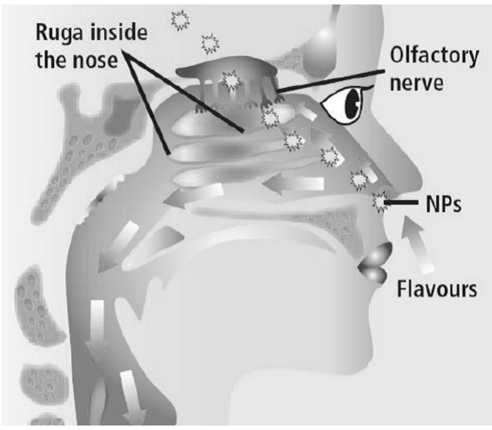

Fig. 2 Human nasal passage system [2]

Ingestion is another route. This mostly happens when a worker who has handled or got in contact with nano-particles does something, like eating, that causes nano-particles to have a hand to mouth transfer. Not enough information is available on adverse effects of ingesting nano-particles on body health.

The third way is skin penetration. Studies conducted on natural and cultured human skin show that single-walled carbon nano-tubes and multi-walled carbon nano-tubes can enter cells and cause release of pro-inflammatory cytokines, oxidative stress and decrease viability, also research show that nano-particles with different physiochemical properties could enter intact skin of pig. However; it has been shown that sun creams that contain titanium dioxide nano-particles don't penetrate beyond our outer skin layer.

Now that exposure routes are somewhat recognized it seems useful to discuss the effects of two important nano-particles that may introduce high health risk: one is PTFE (poly tetra fluoro ethylene) and the other one is carbon nano tube (CNT).

PTFE fumes which are freshly generated are extremely toxic for lungs and cause pulmonary edema and death in laboratory rats and it has been reported that the same problems have occurred for workers exposed to great dose of PTFE fumes.

CNTs are usually available in tow forms: single-walled CNT and multi-walled CNT and each one consist of several types. SWCNTs show adverse health effects in rats like granuloma in lung that was not noticed for ultrafine carbon black although they are both carbon-based materials [3,4]. Also researches show that rats exposed to SWCNT were led to pulmonary inflammation, oxidative stress, decrease in pulmonary function, bacterial clearance and interstitial fibrosis. For MWCNTs, both types, ground and unground, caused pulmonary inflammation and fibrosis in rats. It has been noticed that the dispersion of ground CNT was greater in lung and fibrotic lesions were observed in alveolar region of lung, whereas for unground CNTs fibrosis in air way of rats was seen, besides its great biopersistence in body.

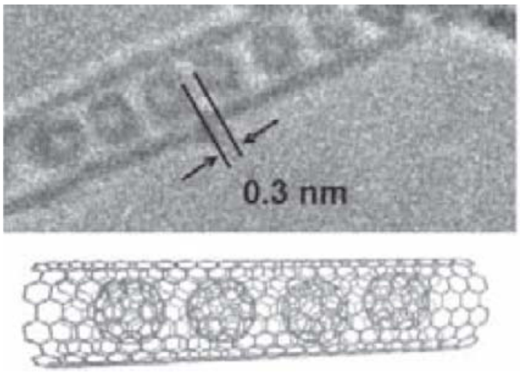

Fig. 3 Carbon nanotube [2]

After all, the main goal of talking about the different effects of nano-particles on body is to create a framework and make some hypotheses to control and anticipate hazards of these ultrafine objects specially at this time that not enough information is available on this field. We can do this job through the ways mentioned below:

- Using available data and information of fine particles' effects on body; for example, we know from studies in human that a great portion of nano-particles deposit in respiratory system compared to larger particles [5,6], so we should monitor this organ of workers with greater attention.
- Using the laboratory information gathered from testing on lab-rodents; for example, we know from animal studies that nano-particles that are deposited in lung can transfer to other organs or nano-particles are more active than larger particles due to their greater surface area per mass.
- Make some guess and hypothesis according to available information; for example, we may say that because of ultra small size, nano-particles can penetrate cell membrane and interact with cell content.

As a conclusion, we can say that nano-particles because of increasing in surface area as the main reason, pose greater human concern such as toxicity and diseases like pulmonary problems compared to large particles, but recently it has been proved that the toxicity of nano-particles can be reduced by engineering acts like change in molecule structure, increase sidewall functionalization of SWCNT and changing type of surface coating and phase composition of nano-crystalline structures.

B. Safety Concerns

At the present time the most important hazards that nano-particles may cause in field of safety are fire and explosion and catalytic reaction. Since there are not much information available on safety risks, we can focus on these two hazards more. In case of fire and explosion, it has been proved that nano-scale powders pose higher risk of safety than larger particles that is due to their small size, since the energy required to initiate the combustion decreases and it may make inert substances absolutely flammable. Also some nano-particles are used as heat generators in chemical and industrial processes that may be considered as a high safety risk if proper controls are not made.

In field of catalytic reaction, nano-catalyzers are of good fame. These particles by reducing the temperature required to initiate the reaction make the rate of process increase significantly but this property may cause some spontaneous reactions that are not anticipated and would lead to explosion or fire in industrial facilities.

C. Environmental Concerns

Researchers and manufacturers who are working on nano-materials to produce a specific property for a special purpose, sometimes wonder about the properties that nano-materials show which they didn't expect to notice or can't explain its reason even under controlled environment under which the test or manufacturing was conducted. So it makes it difficult to predict nano-materials' behavior in the more complex real world situation. Only a few manufactured nano-materials have been used for long period without obvious harmful effects on the environment and other living organs, but for new nano-materials recently being produced there is very limited or sometimes no toxicological information. Among such materials we can name carbon nano-particles, nano-metals, carbon-nanotubes and nano-fibers.

Through different adverse effects of nano-particles on environment, toxicity is of the most importance; so we use the term "Ecotoxicology" that means the study of the fate and effects of anthropogenic chemicals on ecosystems and their component organism to discuss the toxic effects of nano-particles on environment. Studies of manufactured nano-particles' ecotoxicology are in their infancy and there are many uncertainties about the reliability of existing traditional toxicological test procedures and risk assessing to be used for nano-particles. Current ecotoxicological studies have focused mainly on critical toxicity in aquatic species and air pollution, caused by nano-particles not intentionally manufactured (ultrafine particles) and little work has been done to determine the effect of these materials in water, soil, sediments or the atmosphere. One of the difficulties that is the consequence of not having adequate information about nano-materials is that we are not sure whether or not the adverse effects seen in environment is caused by the nano-particles themselves, by a coating or other acquired properties or can be ascribed to the transport tools. An example is a study conducted to investigate the toxicity of C60 fullerenes (carbon nano-particles) and its relation with oxidative injuries in brains of fish. This study couldn't find any relation between this injury and the tetrahydrofuran vehicle that was used to generate aqueous aggregates but another study demonstrated that the toxicity may be associated with tetrahydrofuran decomposition products rather than C60 itself.

However; from the evidences we have received, we are not aware of any evidence of severe adverse effects of nano-materials on ecosystems. Although some studies have identified the potential environmental exposure arising from a range of key engineered nano-particle types, for assessing its hazards our data and knowledge is limited. So it seems essential that for further works and studies in this field we first establish detailed database of contents and use of products containing nano-particles, then try to develop our knowledge about factors and processes that effect transportation of nano-particles and finally comprehend our information about more complex exposure conditions and determining the ecotoxicity of engineered nano-particles under different environmental situations.

IV. Exposure Risk Assessment

Nano-particles are widely different in physical, chemical and biological properties and until enough information becomes available to make exact and definite assessment and control on nano-particles exposure risks, it seems essential to make some preventing and interim actions to lower the risk of exposure to nano-particles. These actions should be done towards developing the safe working culture of workers that deal with processes or material handling of different nano-particles, that means at working places, wearing adequate protective clothes or having breathing masks when doing the job becomes a habit for workers. Each protective action should be conducted according to amount and route of exposure, for example research show that processes that generate nano-materials in gas or powder form or maintaining a production system like cleaning or disposal of nano-materials may cause greater exposure risks and need more careful control and assessing but working with devices composed of nano-structures doesn't introduce great exposure risks.

The factors that should be taken into consideration when assessing nano-particles risks can be mentioned as:

- Amount of nano-particles being exposed;
- The ability of nano-particle to pervade;
- The ability of nano-particle to form airborne sprays or droplets;
- Degree of containment;
- Duration of exposure.

Still there is not any international consensus to create a standard frame work to measure and assess related exposure risks of nano-materials. However; we can do some quantitative assessments to locate more potent exposure points and perform prevention actions if needed. Until an international agreement has been established, we can do some preliminary assessments using traditional sampling methods which are area sampling (getting samples from static locations), personal sampling (getting samples from breathing zones of workers) and real-time sampling that can be static or personal. Personal sampling is usually done to ensure that workers are not exposed to greater dose of nano-particles than is permitted but real-time and area samplings are mostly performed to have a background on how and when an improvement of controlling preventions are required. It means we should have a sampling before starting the production processes of nano-materials and after the production has initiated to compare the two data obtained and see whether or not we have any nano-particle leakage.

There are several ways to get samples of existing nano-particles in air depending on the particle size, the location of sampling, size of sampler and etc. Here we will review some prevalent samplers that are frequently used in industry.

- For aerosol samples, inhalable, thoracic and respirable sampler are used frequently. Selecting which type to use depends on the region of respiratory systems in which nano-particles are more likely to deposit, the size of aerosols and the purpose of measurement. For example, measurement done using respirable sampler suggests that most of inhaled nano-particles deposit in gas exchange part of lung and also this sampler can give nominal amount of nano-particles that are deposited in upper airways and will finally be cleared or move to other organs. Respirable sampler can also give mass-based exposure measurement [7] but when chemical components of sample is needed to be identified, chemical analysis must be done using filter samplers.

- Scanning mobility particle sizer (SMPS) is an instrument widely used to do a real-time measurement of aerosol nano-particles. Use of this sampler because of having high cost and size and also containing radioactive materials is limited at workplaces. Also the poor responding time of 2 to 3 minutes make it unusable at working places with high variety of nano-particle size distributions. Fast mobility-based particle sizing instruments are made to make faster measurements, but because of having fewer channels they are of less resolution than SMPS. Also electric low pressure impactor (ELPI) that uses the combination of diffusion charging and a cascade impactor, introduces a good alternative for SMPS with a good time efficiency of 1 second [8]. For real-time sampling there is also another instrument called optical particle counter that sizes individual particles and converts the measured distribution of nano-particles to mass concentration. This sampler has the limits of being particle size dependent.

- Condensation particle counter (CPC) is a kind of sampler used to measure particle number concentration. Particle number concentration is usually associated with adverse responses to air pollution in some human studies [9,10]. CPSs are available at hand held size, capable of measuring local aerosol number concentration in range of 10 nm up to micrometer diameter particles, allowing the assessment of particle release occurring at different processes and manufacturing. One important point when using most of particle counters is that they are insensitive to particle sources and it makes it difficult to distinguish between accidental aerosol leakage and process-related release of nano-particles. A research has shown that the maximum particle number concentration was associated with emissions from lift trucks and gas burners rather than the main process that was being investigated. As a conclusion CPCs are useful for identifying nano-particles emissions and determining whether or not the controlling measures are working properly.

- Isothermal adsorption is a technique used to measure the surface area of aerosol samples. One of isothermal adsorption methods is BET that requires large quantity of material to do the measurement and its accuracy depends on particle porosity and also adsorption characteristics. The first instrument designed to measure aerosol surface area is epiphaniometer. This sampler measures the active surface area by calculating the attachment rate of radioactive ions. Epiphaniometer is not proper for using in wide range at working places because of containing radioactive sources and lack of temporal resolution. For measuring active surface area there is another instrument called portable aerosol diffusion charger. This sampler is a good tool for measuring surface area of particles smaller than 100 nm in diameter. Besides the existing tools for measuring nano-particles surface area, there are some estimation methods to do the same job using the data gathered from other samplers and establishing mathematical relations based on measured property. For instance, if the size distribution of an aerosol remains constant, the relationship between number, surface area and mass metrics will stay constant; it means that mass concentration measurement can be used to determine surface area concentration if specific surface area (surface to mass) is known. Also size distribution measurements obtained from sample analysis by transmission electron microscopy can be used to estimate aerosol surface area. If measurements are done according to particle number, particle geometry information will be needed to find surface area and in case of mass measuring, information about particle density will be required. If airborne aerosol has lognormal size distribution, the surface area concentration can be calculated through using three independent properties (mass concentration, number concentration and charge) [11]. If we know the response function of each sampler used to measure the three properties, minimization technique can be used to estimate the parameters of lognormal distribution. Then by using the geometric standard deviation of calculated lognormal distribution, surface area of nano-particles can be obtained if two of three independent quantities are known (for example number and mass concentration). However; although such estimating methods are not long term alternatives for more accurate methods, they can be a good approach to find surface area of nano-particles at the time the lack of precise measurement tools are completely obvious.

Now that we have reviewed prevalent measurement tools of nano-materials' characteristics, it seems to be time for having some assessment on nano-particle hazards. As we mentioned among several factors that influence toxicity and adverse health effects of nano-materials, surface area is of the most importance. It means if we have a good and partly exact data and information of the surface area of nano-particles existing in workplaces, we can make assessments and controlling actions to lower risks and hazards that workers would face at industrial places.

From the discussions and reviews we had above, an outline on how to measure particle relating quantities became available, making the assessment of nano-materials' risks a bit simpler. A hazard assessment must take into account dangers associated with the substance and all further adverse effects like mechanical and electrical hazards. Currently there is no sampling method to characterize exposure to nano aerosols, so to achieve this goal there should be a multifaceted approaches which combine many sampling methods and exposure measurements to have a reasonable approach to characterize and assess workplace exposures. This achievement needs some steps to be done:

First step is to determine the sources of nano-particle emissions. As we mentioned before CPCs are good instruments to do this job. It is a necessity to have a background of how much particle is available in workplace before the initiation of process and after starting of manufacturing to compare two data and see whether or not we have nano-particle leakage. If we want to control a certain nano-particle, then area sampling with a filter suitable for analysis by electronic microscopy should be conducted. Transmission electron microscopy can identify specific particles and their size distribution.

The second step is the measurement of aerosol surface area and size distribution which can be done using portable diffusion charger, an SMPS or ELPI. The location of these instruments should be in a place close to working areas but other factors like size of instrumentation and power sources should be considered.

The last step is a personal sampling consists of filters which should be proper for being used in electron microscopy and chemical identification analysis. As we said, electron microscopy can identify particles and their size distribution. In order to measure the particle size of a certain substance (like TiO2) personal cascade impactor or respirable cyclone sampler with a filter might be helpful to remove other substances that are not of interest and make the measurement of particle size more accurate. Then by analyzing of filters for air containment of interest particle, the sources of the aerosol nano-particles can be identified.

So by combining these three steps, the assessment of work exposure to nano-aerosols can be done.

V. Exposure Controls

So far, we have reviewed the properties, measuring tools and methods and assessment of nano-particles present at our environment and workplaces. Now it is time to have a review on controlling acts that should be conducted to lower the risks that these nano-materials with their unique properties would cause specially at this time when not enough information is available on health and environmental risks that workers exposed to nano-particles may face. A good preliminary action to approach this goal is to use different work practices and engineering controls which accompany new techniques that are performed for other general aerosols and it is found to be effective in many cases [12,13]. But still a good and appropriate management program framework should be grounded which contains the following factors:

- Establishment of guidelines and work practices for installing, evaluating and developing engineering controls;
- Education and training of workers on how to handle nano-materials properly;
- Development of procedures for selecting and using personal protective equipment;
- Development of cleaning and disposing nano-materials' waste.

The actions and programs suggested below can be some steps to achieve a powerful risk management framework that is described by the factors above.

Using control techniques like isolating the generation sources of nano-materials from workers (source enclosing) and local exhaust ventilation system for capturing airborne particles can be helpful reducing exposure risk of nano-particles. Current studies show that well-designed exhaust ventilation with a high efficiency particulate air (HEPA) filters can remove most of nano-particles releases from flares and exhausts. In well-designed filter housing, HEPA filters are usually used coupled reducing the potential of nano-particles to bypass them. Also it is strongly recommended that work areas be cleaned up at the end of each work shift using a HEPA filtered vacuum cleaner or wet wiping methods. Using dry wiping and air houses are extremely dangerous because they will cause nano-particles to spread out in air. The wastes collected should be out of workers' reach and should be vacated according to industrial hygienic organizations' recommendation. Workers should also wash their hands and take shower and change their clothes before eating, smoking or leaving work place to prevent illnesses and unintentional contaminant of other areas caused by transfer of nano-materials on clothing and skin.

One of important issues on personal protective programs is to produce fabrics that are of great efficiency in blocking nano-particles. A recent research shows that the efficiency of 8 widely used fabrics against nano-materials range from 0% to 31% [14]. Furthermore even for micrometer powders it was shown that skin protective clothes exhibit limited capability to control and reduce thermal exposures [15]. Still no penetration efficiency for nano-particles have been studied but some clothing standards are doing tests on nano-material sized particles to provide information about the effectiveness of protective clothes to nano-particles.

As we previously mentioned, inhalation is the most potent route for nano-particle penetration in body, so the use of respirators, when engineering and administrative controls fail to adequately keep workers exposure to nano-particles within the limited range, becomes essentially needed. For determining the effectiveness of controls or the need for respirators, it is necessary to consider both the current exposure limits and the increase in surface area of the nano-particles relative to particles for which the limits were developed. So when airborne exposure of nano-particles goes beyond limits, using respirators can reduce workers exposure. Several types of respirators are available for industrial uses which can introduce different levels of protection according to the advantages and disadvantages that are available in different tables. When respirators are required to be used in workplaces a program also should be established that includes the following elements:

- The evaluation of workers ability to perform the work while wearing respirators;
- Regular training of workers;
- Periodic environmental monitoring;
- Testing respirators fitting;
- Respirators' maintenance, inspection, clearance and storage.

One of the factors that influence the efficiency of air purifying respirators is its filtration performance, so many researches and tests are done in this field and some theories are established. One of most famous theories is single fiber filtration (SFF) theory that says "particles larger than 0.3 µm are collected most efficiently by impaction, interception, and gravitational settling, while particles smaller than 0.3 µm are collected most efficiently by diffusion or electrostatic attraction" [16]. Range of the most penetrating particle size [17,18,19]. However; for each filter there is a "most penetrating particle size" (MPPS) that depends on the type of filter media and condition of respirator. According to SFF theory, below MPPS, filtration efficiency will increase as particle size decreases until the particles are so small that they behave like vapor molecules. As particle approaches to molecule size, they may be subjected to thermal rebound theory in which particles bounce through a filter; as a result, particle penetration will increase. The exact size at which thermal rebound will occur has not been reported but some studies show that it happens for particles with about 2.5 nm in diameter [20].

Another issue that should be considered to be done well for a perfect management program is cleaning up and deposing of waste nano-materials. No specific guideline is available on this object so establishing some basic strategies to deal with waste nano-particles and contaminated surfaces, together with considering available information on exposure risks and relative importance of different exposure routes can be extremely helpful. Standard approaches to cleaning up powder and liquid spills include the use of HEPA filtered vacuum cleaners, wetting powder down, using dampened cloths to wipe up powders and applying absorbent materials traps. Energetic cleaning methods such as dry sweeping or the use of compressed air should be avoided or only be used with safety measures that assure particles suspended by the cleaning action are trapped by HEPA filters. If vacuum cleaning is employed, care should be taken that HEPA filters are installed properly and bags and filters are changed according to manufacturer's recommendation.

When using procedures for cleaning up nano-material spills and contaminated surfaces, attention should be given to the danger of inhalation and thermal exposure during cleanup and consideration will be needed for using proper personal protective equipments.

VI. Conclusion

Nano-particles because of having changes in some physical, chemical and biological characteristics, show different properties than we expect from larger particles of same kind to exhibit. These differing characteristic that nano-particles get, have both benefits in industrial, medical and other commercial and non-commercial fields and also health, safety and environmental hazards for human beings and other species. Since this science is in its infancy stage now, not enough information is available about the adverse effects off nano-particles on environment (including human and nature), but we can have some hazard estimation by using existing data for larger micro meter particles' properties, tests done on laboratory rodents and reported diseases that workers exposed to nano-particles have got. Also in risk assessment aspect, scientist have found that increase in surface area is the main reason that is associated with nano-particles exposure hazards, since this increase in surface area causes nano-particles to become more active and show toxic properties that we didn't anticipate for such materials to show and this surface increase also make nano-particles more flammable, increasing the risk of fire and explosion in workplaces. So determining the amount and size of nano aerosols exist in workplace is a necessary hazard prevention step and by identifying leakage sources and applying essential managing measures we can control and reduce exposure risks associated with nano-particles.

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