Aerotoxic Syndrome and Low Level Exposure to Nano Particles

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In this article the author attempts to explain the possible adverse health effects on humans that can result from exposure to and inhalation of ultrafine toxic particles, in particular after inhalation of jet-engine oil fumes/smoke on aircraft.

The air enters the aircraft cabin unfiltered. If the engine seals are worn or fail completley or if the engines are improperly serviced (*e.g.overfilled/overserviced with oil, as has been stated to be the possible reason in a recent fume event on a Lufthansa German Airlines A388)* oil fumes or smoke/mist may enter the cabin. Disturbingly, it seems that certain engine seals appear to allow some leakage of oil into the bleed air system even under normal operating conditions due to (faulty?) manufacturing.

In this article the term nano particles is used in lieu of the words“ultra-fine” particles; these particles can be generated by various chemical compounds and chemical reactions of interacting chemicals under certain conditions, duress and temperatures. They are used in e.g. lubricants, antiwear additives for engine lubricants, engine oils, fuels etc . Various oil manufacturing companies seem to be advertising their oil's/lubricant's improved performance to be based on nano technology (e.g. “Multisol”).

The uptake of nano (and micro) particles has been in the focus of many investigations going as far back as the seventeenth century (2), while more recently entire scientific journals have published articles on the subject (5). The absorption of nano particles via the gastro intestinal tract, or the colonic mucous layer, the lymphatic system, the respiratory system etc, depends on the size of the nano particles and the length of time of exposure and uptake. Particles that penetrate the mucous are able to translocate further. (4)

Every person has been exposed to nanometer sized particles which are inhaled with every breath or ingested with food and beverages. The vast majority of these nano particles are even produced in Nature, are not

harmful and will be unnoticed, but occasionally some will cause harm to the person exposed to them.

Virusses are amongst the most advanced nano particles with familiar ones being the flu or common cold virus, which are composed in such a way that they can interfere with the biological system and bodily functions and subsequently damage cellular processes.

One may think that nano particles (e.g.ash, dust) that are similar in size to virusses might be more benign since they cannot replicate themselves as virusses do. However while they don't directly interfere with cellular processes, some have been shown to interfere with the cellular function, influencing the basic process of cells, such as metabolism, proliferation and death. Nanoparticles are small enough to penetrate cell membranes and defenses, yet they are large enough to cause trouble by interfering with normal cell processes, researchers at the University of Massachusetts say. (15)

Nano particles have the ability to enter and damage living cells of humans and animals. This ability allows them to pass physiological barriers and to travel throughout the circulatory system, and like virusses, they can penetrate lung or skin barriers and enter the lymphatic system, reaching bodily tissues, disrupting cellular processes and even causing disease.

Modern science has learned how to manufacture synthetic nano particles in a huge array of different products - with the smallest particles containing tens or hundreds of atoms with dimensions at the scale of nanomaters, thus called nano-particles. Synthetic products are generally not easily or well absorbed or metabolised by the body.

Nanomater sized particles are produced in countless processes from erosion to combustion, with

health risks ranging from benign to lethal.

Asbestos which exists in several forms is a good example of toxic nano material causing lung diease and lung cancer with slight variations in

toxicity.

There seems to be a distinction between fixed (nanostructured) and detachable free nanoparticles . Fixed nano particles such as film coatings, microchips or electronics are known to be mainly benign, while uncontained nanoparticles clearly cause adverse health effects.

A certain percentage of the population seem to be more sensitive and appear to be at greater risk to exposure and the toxic effects of particulate pollution. Inflammation and certain already existing diseases (e.g. diabetes) seem to cause a greater risk since the inflammation might enhance the translocation of the nano particles into circulation and in through the blood brain barrier. In additon to immediate reactions, time series studies have shown that a cumulative effect over a long period of time (weeks, months or more) is associated with elevated particulate concentrations exposure - studies are being undertaken to determine the long term health effects from being chronically exposed to nanoparticles.

Inhalation and Low Level Concentrations

Dispute over so called “low level” (under the legal threshold) concentrations are ongoing, but none seem to take in to consideration the fact of nano particles exposure and DNA damage, resulting in symptoms and mild to severe health effects in many people.

In the last decade toxicological studies have demonstrated that small nano particles cause adverse (respiratory) health effects, typically causing more inflammation than larger particles made from the same material. (6) (7) (8) (1)

After inhalation nanoparticles deposit themselves throughout the respiratory tract - which would explain some immediate reactions (1/chpt 4 pg 52) . (*ex/author: sniffling, swelling of sinusses, coughing, wheezing, asthma-like symptoms, headaches,dizziness)*.

Rat studies based on inhalation of low concentrations of 15nm diameter silver particles have shown that soon after inhalation (ca 30 min later) nanoparticles are distributed in the blood and travel throughout the body

and to the brain, and subsquently to other organs such as heart, kidneys, liver. Hence minute concentrations of nanoparticles smaller than 100nm can have a higher probability of translocating throughout the circulatory system and mentioned organs including the brain and cause damage. (1/ pg 53)

The adverse effect of inhaled nano particles on the lungs themselves depends on the burden and on the residence time of the nano particles in the lung. (1/ pg 54). For example carbon nanotubes are not eliminated from the lungs or only very slowly - which, due to the long period of time it is present can lead to lung cancer .

Recent research has brought about the realisation that no particles are completely inert and that even low concentrations of particles can have adverse health effects, the severity of which depends on if the particles reside in the respiratory tract (or i.e. brain). Smaller particles have a higher toxicity than larger ones of the same composition and crystalline structure, thus generating a higher inflammatory reaction within the lungs. Particulate uptake and resulting health damage may be dependent on genetic suscebtability and health status. In the mean time discovery has been made that depending on their localisation inside the cell the nano particles can damage organelles or DNA or ultimately cause cell death ! Many Aerotoxic Syndrome affected patients have certain DNA damage which does not allow proper detoxification via the liver.

The research has also shown that the inhalation of nano particles can affect the immune system and its ability to defend itself against infections.

Both in vivo and in vitro studies have shown that nano particles of various compositions (fullerens,

carbon nanotubes, (car) exhaust fumes) create reactive oxygen species which have shown to damage cells by altering proteins, disrupting DNA, interfering with signalling functions and modulating gene transcription.

Oxidative DNA damage markers showed higher level on workdays in bus drivers from central areas compared to bus drivers from suburban

areas of Copenhagen (10). Nasal biopsies from children living in Mexico city showed greater DNA damage than children living in less polluted rural areas.

Ultimately the interaction of nano particles with cells may lead to DNA modifications, cell injury and disease. (9)

Summary : Inhaled nano particles may represent a potential health risk. Aerosols (fumes) in workplace environments may be derived from a wide variety of sources, depending on the type of activity and processes taking place. Nanoparticle aerosols (fumes) arising from mechanical processes (e.g. the breaking or fracture of solid or liquid material) are unlikely to be formed.

Grinding and surface finishing typically releases micrometre and submicrometre particles, possibly down to 100 nm but rarely below this. Most plasma and laser deposition and aerosol processes are performed in evacuated or at least closed reaction chambers. Therefore exposure to nanoparticles is more likely to happen after the manufacturing process itself, except in those cases of failures during the processing (Luther 2004).

In processes involving high pressure (e.g. supercritical fluid techniques), or with high energy mechanical forces, particle release could occur in the case of failure of sealing *(e.g. bleed-air/ seals*). Nanoparticles exhibit increased diffusivity with decreasing size and therefore show delayed sedimentation in the earth's gravitational field, which translates into potentially increased lifetimes for nanoparticulate impurities at low concentration.

In the presence of larger microparticles, as with the wide size distribution in aerosols such as smoke, the highly diffusive character of nanoparticles may lead to faster agglomeration or impaction on the larger particles. (3)

Many studies indicate that nanoparticles can be eliminated quickly via the feces within 48 hours and the remainder via the urine (e.g. Tricresylphosphates' metabolites) and this author has recently received reliable information of confirmed detection of disphenylphosphate, a

TCP metabolite in the eluate of an airline flight employee 2 years after exposure to a fume event in 2011. As mentioned above other studies indicate that nano particles can translocate to blood, lymphatic system, kidneys, liver, bone marrow, lungs, brain and can also be found in the stomach and small intestine (11).

Comparing the health effects of inhaled nano particles with different sizes, it is remarkable that the low dose exposure (10m3) to 20nm diameter particles resulted in greater lung cancer incidences. (11)

It is believed that the most important parameters in determining the adverse health effects

of nano particles, are dose, dimension and durability (12). Discussions are about what are most important parameteres in deciding their toxicity, mass, number, size, bulk or surface chemistry, aggregation or all together.

Dose is defined as the amount or quantity of a substance that will reach the biological system. The dose is directly related to exposure or the concentration of the substance in the relavant medium (air, food, water) multiplied by the duration of contact. than the high dose (250mg/m3) exposure of 300nm diameter particles (4) (1).

Quote: “We must emphasise that epidemiological studies do not indicate the existence of a threshold below which there are no adverse health effects.” *(Biointerphases vol. 2, issue 4 (2007) pages MR17 - MR172)* Which would eliminate any discussion about “no danger or adverse health effects due to (only) low level exposure”.

Some MSDS state e.g. (16) “Occupational exposure limits : No exposure limit value known.

As mentioned from a quote above and worth repeating : “...there are no epidemiological studies indicating the existence of a threshold below which there are no adverse health effects.” (*in this discussion referring to*

jet engine oil/fumes, including TCP, TCoP and esters).

It should also be noted that toxicity test data are usually available only for pure substances, that is for the active ingredients or solvents used in formulations rather than for the formulations themselves." (16)

Due to the possibility of interactions the combined effects of inhalation, ingestion and/or dermal contact of nano particles with other nano particles or chemicals and gasses seem to be a matter of further research. The presence of oxygen, ozone and transition metals leads to the creation of reactive oxygen (10), species and the induction of inflammation. (13) (9).

Applications currently entering widespread every day use are: filtration, surface disinfectants, diesel and fuel and oil additives (lubricants) , automotive components, hazardeous chemical neutralisers, dental materials, electronics, pharmaceuticals.

Lubricants " .....unique inorganic nanospheres that can be used as dry lubricants, coatings, and for impregnating parts. The new material reduces friction and wear significantly better than other layered solid lubricants and is especially useful in self-lubricating, maintenance-free, and oil-free applications of the types encountered in aerospace markets. Suitable applications could include rotors, bearings, robots, planetary rovers, space vehicles and transport devices." (14 pg 65/66)

Nano particles from lubricants containing neurotoxic organophosphates (i.e. TCP. TCoP etc) which are more likely than not to be present in the (contaminated) cabin air found on a high percentage of aircraft during tests, seem to be clearly causing the above indicated adverse health issues.

Under normal operational conditions of an aircraft 0 (zero) nanograms of TCP and other components of engine oil /lubricants should be found in the cabin (work) environment.

"Occupational exposure limits No exposure limit value known". (quote 16)

Manufacturers and airlines have a duty of care to determine how such contamination can happen and how neuotoxic agents, organophosphates and nano particles thereof get in to the interior and on to surfaces of all the aircraft in which it has been detected and subsequently in to the lungs and on to the skin of crews and passengers. There is no dispute about the neurologic toxicity of OP's (Ref: MSDS TCP).

Quote (16) “Whilst specific OELs for certain components may be shown (in this section) , other components may be present in any mist, vapour or dust produced. Therefore, the specific OELs may not be applicable to the product as a whole and are provided for as guidance only.

Also manufacturers state in their MSDS's for the turbine oils, (e.g.16) “Delayed and immediate effects and also chronic effects from short and long term exposure” (16).

The entire aviation industry clearly knows about these issues (since 1955), stating (16 quote) “Exposure to decomposition products may cause a health hazard. Serious effects may be delayed following exposure. May be harmful by inhalation if exposure to vapour, mists or fumes resulting from thermal decomposition products occurs. Overexposure to the inhalation of airborne droplets or aerosols may cause irritation of the arespiratory tract.” (16 unquote), and thousands of people have serious and chronic health issues due to over-exposure *(e.g. pilots, crew and frequent flyers)*, not to exclude the possibility of a severe fume event in which just one incident/exposure can cause serious nervous system damage. To date the manufacturers and airlines have failed to provide explanations as to how the cocktail of toxic fumes including the TCP/ TCoP's etc get in to the cabin air. More

than that, they have not even tried to explain it, because it seems they know that they can't refute the bleed air argument.

In light of above information, which is only a very small excerpt from the vast amount of scientific material available on the subjects, this author comes to the conclusion that airlines and aviation industry manufacturers should take appropriate measures to protect their clientele

and employees from jet engine oil fumes entering the aircraft cabins, and until these measures have been set in place to notify in advance passengers and crews who may become exposed to jet engine oil contaminated cabin air on aircraft of the possibility and the potential health risks, and initiate active illness surveillance and support among exposed and injured employees and passengers.

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(4) (5)

(6)

(7) (8)

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MSDS AeroShell Turbine Oil 560 (this is an example and applies to other brands also. excerpts/quotes) *Whilst specific OELs for certain components may be shown in this section, other components may be present in any mist, vapour or dust produced. Therefore, the specific OELs may not be applicable to the product as a whole and are provided for guidance only.*

Section 8) Occupational exposure limits No exposure limit value known.

If inhaled, remove to fresh air. Get medical attention if symptoms appear. In case of inhalationof decomposition products in a fire, symptoms may be delayed. The exposed person may need to be kept under medical surveillance for 48 hours

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Whilst specific OELs for certain components may be shown in this section, other components may be present in any mist, vapour or dust produced. Therefore, the specific OELs may not be applicable to the product as a whole and are provided for guidance only.Environmentla exposure controls: Emissions from ventilation or work process equipment should be checked to ensure they comply with the requirements of environmental protection legislation. In some cases, fume scrubbers, filters or engineering modifications to the process equipment will be necessary to reduce emissions to acceptable levels

Inhalation Section 11) Delayed and immediate effects and also chronic effects from short and long term exposure

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