FINE DUST OR NANOPARTICLES? WHAT'S THE MATTER? WHAT IS IT ABOUT?

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Abstract

Nanoparticles, so tiny that they are invisible, smaller in diameter than the wavelength of visible light, are extremely harmful to human health, much more so than fine dust in the PM10 - PM1 range. If you compare them in size, it's like a pinhead versus a truck wheel. Diameter spectrum of visible particles ranges from about 1μm to about 50μm. PM emissions of new vehicles are very low now, measuring method of PM has already found its limits. For about 20 years there has been thorough and intense research into invisible nanoparticles, size range form about 5 nanometres to 500 nm (1000 nm make one micrometer or 1 μm). There are suitable measuring systems allowing counting those nanoparticles. Due to inherent properties of Diesel engine combustion, those nanoparticles are always generated. About 5% of fine dust in Germany may be attributed to diesel engines. This disregards completely nanoparticles, because they are 100 to 1000 times smaller and their contribution to the mass is negligible. However, just these nanoparticles are most dangerous due to their composition. Introducing Diesel Particle Filter as serial equipment in Diesel engine driven limousines by PEUGEOT was a historic event and demonstrated that reliable DPF's being feasible in mass production and economically viable, filtration efficiency of nanoparticles is excellent, cost increment is such that it need not be separately charged to the customer. Measuring techniques based on mass become troublesome as soon as particles size is smaller than 1 μm. The counting criterion was officially proposed to the High Commission of the EU by Switzerland, later on seconded by Germany and France. In that case particles are not any more placed on a scale, they are counted only, a method borrowed and adapted from nuclear physics.

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1. Just to the point

- Nanoparticles, so tiny that they are invisible, smaller in diameter than the wavelength of visible light, are extremely harmful to human health, much more so than fine dust in the range of PM10-PM1. If you compare them in size it's like a needle head versus a wheel of a truck and their composition makes them even more troublesome.
- Combustion in a Diesel engine is quite an inhomogeneous process such that combustion is never perfect, even newest engines, of most recent engineering development, the particle mass of which is almost zero, even those engines release almost the same number of nanoparticles into the air as their precursors did.
- At present, exhaust gas particle filters constitute the only method to get rid completely of all particles, visible and invisible.
- Preference, whether retrofitting or engines already originally equipped with DPF (= Diesel Particulate Filter) isn't just a matter of engineering, there are other considerations important as well. While on the on hand retrofitting may be recommended for public fleets almost any time, passenger cars should not be subject to retrofit, only buying cars originally equipped cars with filter of proven filtration efficiency is making sense.

2. Why Particle Mass?

Who has never experienced black smoke from a diesel engine? If a student candidate defending a thesis in internal combustion engines says: „It's soot", he is only partly right, he has not sufficiently replied. He should know that within and on this cleft kernel of soot there are adherent various hydrocarbon molecules, sulphates, phosphates and some oxides of metals; the latter one predominantly stemming from lube oil. A spicy conglomerate is generated causing headaches for toxicologists.

Diameter spectrum of visible particles ranges from about 1 µm to about 50 µm. Due to legislation these particles are limited by mass (PM - mass of particulate matter). Already decades scholars discuss and work regarding identifying single toxic effects; in occupational health only the carbon-kernel (elemental carbon) is the criterion of limitation while other experts see the danger in adherent hydrocarbons and oxides of metals. In contrast there are also experts of toxicology who do not see any causal chain, regarding all effects of those substances as insignificant. To some extent, there is so much belittling, that one may be tempted to ask: „Why aren't those substances sold for miracle cures in spas and pharmacies?"

Nowadays, diesel engines do not exhibit any remarkable black smoke anymore, particle mass may still be measured, legal limits of PM-emissions have been lowered in regular intervals, PM emissions of new vehicles are very low now, measuring method of PM has already found its limits.

3. Counting numbers of particles

For about 20 years there has been thorough and intense research into invisible nanoparticles, size range form about 5 nanometres to 500 nm (1000 nm make one micrometer or 1 µm). There are suitable measuring systems allowing to count those nanoparticles. Due to inherent properties of Diesel engine combustion those nanoparticles are always generated; even if measured by mass (PM) there is almost nothing to detect. Wavelength of visible light is from 400 to 800 nm, hence light-waves more or less circumvent these particles.

Measured size distribution exhibit a maximum in concentration of about range of 1 to 10 million particles per millilitre of air (1 cm^3) ranging from about 80 to 100 nm.

Just, try to imagine: 1 million particles per ml that is 1000 particles per mm^3! Those are embedded within the air flow like molecules and thanks to their composition they carry a variety of potential risks with them - an infinite microcosm.

Methods of modern research, for instance radioactive tracing enabled scientists to provide evidence of how fast those nanoparticles penetrate into cells of human or animal organs. They find the way into blood vessels and into the nervous system; wherever they may exert their harmful effects. Dangerous potential of nanoparticles from combustion is well proven.

The further discussions about toxicological and epidemiological causalities - which are scientifically interesting, but cannot lead to any result in the usefull time - are not necessary for the legislation any more. This can be stated at least for some industrialized countries, where - according to the principle of prevention - the legislation has to help the peoples on time and at place, as soon as the necessity is recognized.

4. Fine dust

In environmental air quality mass of all sorts of dust is measured after the gas has passed pre-filtering; by this method size fractions up to 10 µm, 5 µm, 2.5 µm or even 1 µm are obtained. Accordingly, emissions are denoted PM10, PM5, PM2,5, or even PM1. Those dusts have different sources, like abrasions, whirl-ups, biologic sources, industry, or residential. According to a recent study of German car makers about 5% of fine dust in Germany may be attributed to diesel engines. There are also other papers around, with finding of almost 90% originating from Diesel engines in

specific locations. Though this way of looking at things disregards completely nanoparticles, because they are 100 to 1000 times smaller and therefore their contribution to the whole mass is negligible. However, just these nanoparticles from combustion are most dangerous due to their composition.

5. Particle filters for exhaust of Diesel engines (DPF)

Principle of filtering diesel engine exhaust is pursued for at least 30 years. While the engine is running the filter is increasingly clogged and has to be burnt free, which is called „regeneration". Initiating regeneration and controlling is not so easy; various problems may occur, even self-destruction of filter may occur. During the last 15 years industry and other research institutions worked hard in developing systems of monitoring state of filter and controlling regeneration.

6. Retrofitting

A tremendous progress in filter techniques and retrofitting was brought about by a project of the occupational health authorities of Switzerland Austria and Germany, SUVA, AUVA and TBG and joined by the Swiss EPA, called BUWAL. When designing tunnels for Alpine transversals, experts of occupational health and construction had recognised the week point in tunnelling extremely long sites was in ventilation. A project, called VERT, an acronym for improvement of the air in tunnel construction, lead to the conclusion that deployment of DPFs is substantially reducing ventilation requirements.

There was a need for:

- quality-verification and a list of DPFs to be recommended,
- field control tests,
- consulting services for users.

Switzerland became the first country having estableshed a quality control system for DPFs in retrofit, a fact which drew worldwide attention. Filters certified according to VERT separate at least 80% of particle mass and 99% of nanoparticles. At present DPF's constitute the only and the most efficient way to get rid of nanoparticles. Todays technology enables filtration efficiency up to 99.999%. In legislation to come number-count of nanoparticles is to become an additional criterion of international laws on exhaust of vehicle emissions. Then it will not be feasible to satisfy legal requirements without DPF's.

Swiss experts mandated by ASTRA, the Swiss Road Authority and by BUWAL, the Swiss EPA took part in an international task force of the EU and the UN; it was named GRPE PMP (Particle Measuring Program); they shared their experiences and on top of this participation they contributed to quite some retrofit projects outside of Switzerland.

7. OEM (Original Equipment Manufacturer)

Introducing DPF's as serial equipment in Diesel engine driven limousines by PEUGEOT was a historic event. Legally there is already plenty of electronics anyway, the OBD (on board diagnostics); consequently, monitoring of filter back pressure as well as triggering and control of regeneration was integrated into OBD. PEUGEOT demonstrated that reliable DPF's being feasible in mass production and economically viable, filtration efficiency of nanoparticles is excellent, cost increment is such that it need not be separately charged to the customer.

Public pressure led other European manufacturers following suit - 2 years later. Particle filters became optional equipment just for supplement cost and preferably for the more expensive models only. First time in automotive history an exhaust after-treatment system was introduced without preceding legislation, only due to public opinion. No doubt, there was evidence of engineering feasibility, regarding economic effects there remained some doubts.

8. What ought to be retrofitted, and what to be left to OEM.?

DPF-technology is feasible and very efficient regarding filtration of visible and invisible solid particles. However, there is such a variety in applications of Diesel engines working under different conditions, what makes it advisable to differentiate.

Primarily, retrofit should be done for fleets, singled out according to their air-polluting effects and having clear rules regarding costs. Waiting for legislative procedures (until new laws go into effect) is rather time consuming and renewals of fleets may even take longer.

9. Retrofitting

There is more to retrofit than just engineering functionality: liabilities, warranties among manufacturer of engine, DPF-supplier and users have to be agreed upon.

Properly adjusted retrofit-systems do not influence parameters of engine performance; advantages, however, are to be felt at the location immediately. Retrofit has always been a success, if there is some good comprehension of the DPF-function by personnel involved - if the „new device" and responsibility for it are accepted. Retrofit means there are additional costs (of investment and of operation) and more work to be done. Of course, these are reasons enough for management and labor seeing retrofit as being not acceptable. Furthermore, it is not difficult to understand the most frequent objections:

a) „too expensiv" - one has to ask: For whom? Who pays? Who ought to pay? How much are we prepared to pay for our own well being and how much for public health?
b) „Techniques are not mature" - This means, this person does not know the variety of existing engineering solutions; may be this person is not even willing to look around and to get down to the bottom of problems involved.

Despite these resistances, it was demonstrated that retrofit is working well on construction engines underground and above. Commencing end of the ninetieth supporting industries have developed providing DPF-systems of high quality; One may find them in the list of recommended DPF's of the Swiss BUWAL (see www.umwelt-schweiz.ch - check VERT Filterliste) or otherwise check the home page of the filter manufacturers' task force akpf www.akpf.org/.

City busses and communal vehicles ought to be subject to retrofit; budget decisions depend on more than just one level. It is very important to inform decision makers sufficiently; due to the number of persons involved it is rather cumbersome; nevertheless extremely important, to provide them with technical information of immaculate quality.

It's not surprising that in the variety of media quite different opinions appear, let alone information, absolutely wrong from an engineering viewpoint.

Who should pay?

Obviously, public health is a topic seriously touching the interest of the public's purse; therefore, public funds should be made available at least during the start-up period. One should not forget retrofit is only for a transition period to general OEM equipment.

10. Originally Manufactured Equipment

Unfortunately, buying departments of cities or instance had not been sufficiently and properly informed earlier; otherwise they would have ordered already busses or special duty vehicles with DPF because they had been available as OEM for several years.

Local sellers frequently fended off, presumably due to their interest in keeping margins large and liability for the aftermarket small.

Statements like "We satisfy EURO-limits even without filters" are just half the truth: de jure right, de facto the most hazardous fraction ignored. Medical effects of nanoparticles are already evident, almost univocal in the profession, and hence even recently as such designated by the WHO (World Health Organisation). At present particle filters constitute the only method to

eliminate this component almost entirely. It is absolutely wrong to buy EURO3, EURO4 or EURO5 city busses not equipped with DPF! - sparing the seller at expense of public health paid out of the public purse !!!

In view of the most recent exhaust-legislation European manufacturers of HD vehicles decided for the DeNOx-Technology. Elimination of nitrogen-oxides is based on injection of a reduction agent (Ad Blue) into the exhaust gas just prior reaching a suitable catalyst; it's called selective catalytic reduction (=SCR). The decision in favour of SCR postpones DPFs as standard OEM for quite some time.

Notwithstanding, various developments of combination are under way and pursued with high priority. No doubt, NO_X is toxic; engineering decision to provide priority of NO_X reduction versus elimination of nanoparticles, was decision which contravenes medical opinion. Ultimate solution will be an in-line combination of both, DPF and DeNOx.

Regarding passenger cars, the engineering solution of PEUGEOT has brought about lots of discussions between German automotive industry and the German government. This led to tax incentives for DPF equipped passenger cars. However, there was a draw back: „nanopartilces" had been disregarded as non-limited components and furthermore, considerations are missing with regard to required filtration efficiencies, quality of filters.

Consequently, this attitude resulted into the suggestion of retrofitting passenger cars with so-called particle-catalysts. Those devices are not particle-filters at all, marketing specialists drew up a notation, which simply constitutes misrepresentation! These particle-kats, also "PM-Kat" denoted, collect at best 30-40% of nanoparticles and about 60% of visible particles (PM). They need not necessarily regeneration, in case of too high a back pressure without reaching regeneration temperature, they simply blow off the full load into the atmosphere.

PM-Kats are perverting the notion of particle filter and they do not exhibit a quality of filtration as has been agreed upon in international co-operation of Swiss and other authorities, already brought on the market by many manufacturers of such DPF's.

Swiss experts networking in nanoparticles think retrofit of passenger cars does not make sense; incentives should be provided for new cars oem-equipped with filters satisfying a filtration efficiency which is state of the art, i.e. corresponding to VERT-criteria or upcoming German TRGS 554.

11. Desorientation, opportunistic attitude

The gentle reader my have become aware, the topic addressed comprises engineering, commercial, social, political and ethic aspects. If any information on radio or TV is limited to 2 -3 minutes, one need not expect more than a superficial description, which may be worse than none; a half-truth is usually worse than an outright lie. In our opinion, careful information of public multipliers is highly desirable, for instance teachers in physics, chemistry, biology. As an example of an almost organised basic disinformation of the public may serve the mix-up of notations without precise definitions:

The notation „fine dust" is taken in the context with emissions of Diesel engines, while systematically nanoparticles and their corresponding health effects are ignored.

In public discussions all PM10 is regarded as „fine dust", which is - as mentioned previously - the sum of all fraction up to 10 µm; the biggest carrying most of the weight. (it's the legal criterion in Switzerland and the European Union).

In the United States an additional legal criterion has been introduced, PM2,5; the difference PM10 minus PM2,5 is called the coarse particle fraction. They recognised earlier than Europeans, that health hazard is increasing with decreasing size.

Measuring techniques based on mass become troublesome as soon as it comes to nanometres, i.e. as soon as particles size is smaller than 1 µm (imagine just determining the weight of one single mouse riding an elephant taken to a weigh-bridge (elephant with and without mouse). The

counting criterion was officially proposed to the High Commission of the EU by Switzerland, later on seconded by Germany and France. In that case particles are not any more placed on a scale, they are counted only, a method borrowed from nuclear physics and adapted.

Caution is to be recommended versus too much of an optimism as well: There are both around, idealists and there are basically very conservative attitudes resisting any change even mentally; the latter may be seen as a positive element in human society as well: dissenting opinions make society progressing at a reasonable pace.

Information may be blurred for various reasons; however, one shouldn't give up due to so many dissonances, even if we are confronted with utterances „…this is not part of EU-legislation"

Necessarily, any legislation is dragging behind new knowledge of science ! May active public discussion contribute to an understanding of problems involved!