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IMPACT OF DIESEL ENGINE EXHAUST GASES ON ENVIRONMENTAL POLLUTION AND HUMAN HEALTH

ABSTRACT

Fine particles that can be found in the exhaust gases of diesel engines and have a diameter of 2.5 μm and ultra-fine particles of 0.1 μm in diameter are mainly products of the combustion process. Experiments on animals have proven that the particulates from the ambient air can cause damage to the lungs and can even end fatally. Therefore, it is necessary to reduce the mass of fine particles in the atmosphere and the number of ultra-fine particles. Numerous studies of experiments on animals have proven the toxicity of these particles. The air saturated by particles resulted in cardio-pulmonary diseases in animal models. The epidemiological studies have shown the interdependence of the increase in mortality and morbidity, especially in the elderly and persons suffering from respiratory ailments and cardio-vascular diseases. A hypothesis has been set that the ultra-fine particles cause inflammatory reactions in alveoli and interstitium resulting in the increase of blood coagulation and deterioration of the condition in persons suffering from the problems in cardio-vascular system.

KEY WORDS

diesel engine exhaust gases, air pollution, particulates, inhalation, respiratory ailments, cardio-vascular diseases

1. INTRODUCTION

Health hazards for people caused by the emission of soot and particulates generated by diesel engines are being researched by the leading doctors and institutes who do not deny this impact any more and partly confirm it. The vehicle users and consumers have to be seriously informed about the advantages and the disadvantages of the Diesel engines. On the other hand, the automotive industry has recently invested substantial efforts in improving the level of efficiency of the diesel propulsion, efficient reduction or partial elimination of the emissions.

Today, particulates are divided according to their size into airborne dust, which can be inhaled and can penetrate the lungs, and into ultra-fine particles in nanometric ranges. Traffic represents a significant source of fine and ultra-fine particles. There are also secondary changes where primary particle interacts with other particles.

The studies of acute and chronic exposure are used to find the mechanisms of actions and long-term effects. According to WHO [1] there are clear relations between the increase in the concentration of particulates over a given duration of exposure and the increase in the health hazard and mortality. It is precisely the fine particles that can hardly or not at all be eliminated in a natural way from the respiratory tract. This results in medical problems such as the respiratory tract diseases or, more recently, in the proven cardio-vascular effects. The number of cases increases by the greater load of particulates, at the same time increasing the tendency to blood coagulation and changes in heartbeat frequency. The studies carried out in Erfurt have shown that the function of lungs is reduced with higher concentrations of particulates in the inhaled air. The measurements in Erfurt have shown relative shift in the increase of ultra-fine particles. This is to a great extent due to the automotive traffic although this is not a specific problem of the Diesel (the share is about 15 per cent). Further observation refers to the period during which the ultra-fine particles remain in suspension in the atmosphere. Recently, the duration has almost doubled. Correlations with other possible magnitudes of impact have shown that the concentration of particulates is relevant for the health and that other harmful substances in the air play a minor role. The measures undertaken to maintain the cleanness of air have recently included mainly the coarse particles, whereas the share of fine and ultra-fine particles with their negative effects on human health was not treated adequately.

2. DIESEL ENGINE EXHAUST GASES

2.1 Classification of particles

From the environmental aspect, there is the airborne dust that can be inhaled (PM_{10}; diameter < 10 μm), suspended dust which reaches the lungs (fine particles $PM_{2.5}$; diameter < 2.5 μm) and ultra-fine particles (UP, diameter < 0.1) (PETERS et. al. 1998). In the field of occupational medicine, the respective designation is "alveolar fraction (fine dust)", which approximately corresponds to the suspended dust that reaches the lungs ($PM_{2.5}$).

Fine particles of a diameter below 2.5 μm and ultra-fine particles with diameter below 0.1 μm are generated mainly by the combustion processes. The epidemiological studies on the environment show an increase in mortality and morbidity, especially in respiratory tract ailments and cardio-vascular diseases. This negative impact on health can be also found below the valid marginal values for fine particles. A point of reference for the threshold of risk could not be found. There are no studies on ultra-fine particles at workplaces, and in the studies on fine particles only the data on concentrations which have impact on the function of lungs are available. Data on experiments carried out on animals show that fine and ultra-fine particles can cause pneumonia which in animals that had pre-existing pulmonary problems led to death. Currently it is not clear which pathophysiologic mechanisms lead to such cases.

2.2 General description of substances

Suspended dust describes solid or liquid substances that have a diameter between 1 nm and 100 μm suspended in gases. In this way they create airborne substances which are called particles or particulates, together with gaseous colloid systems, marked as aerosols. Solid substances include seawater salt grains from the ocean, mineral particles from volcano eruption and soil erosion, soot particles with organic and inorganic components and particles with heavy metals from the industrial processes. Apart from these non-living solid particles there are also biogenous particles which include viruses, spores, pollen, bacteria and fungi. On the other hand, water droplets in fog and clouds are liquid particles. Depending on the thermo-dynamic conditions and share of the water vapour in the air the hydroscopic particles are suspended as solid or liquid particles. The particles can be primarily formed by condensation of evaporated substances or by surface dispersions, i. e. mechanical crushing of solid or liquid materials. Figure 1 shows the diameter of some typical particles. The chemical reactions of gases, such as sulphur dioxide (SO_2), nitrogen oxide (NOx), and ammoniac, convert secondary particles into acids and salts. Airborne dust in the atmosphere in Europe consists mainly of sulphates, nitrates, ammoniac, organic compounds, elementary carbon, metal and water.

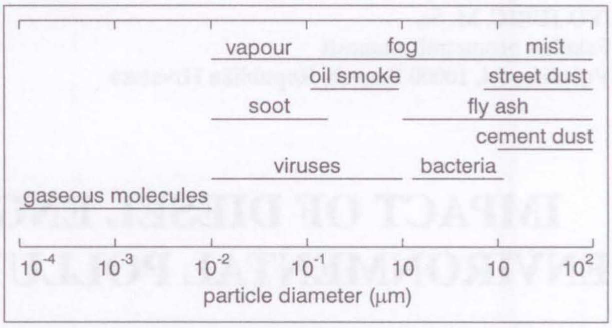

Figure 1 – Size of typical particles in the ambient air

The emission of airborne dust in Germany fell from 2.02 million tonnes in 1990 to 755,000 tonnes in 1994 [2]. These figures refer to the overall airborne dust designated in the English language as TSP (total suspended particles) (Table 1). Figure 2 shows the sources of these particles in Germany based on the figures from 1994 [2]. These values differ significantly from one German federal county to another, e. g. the data for Baden-Wurtenberg for 1993, 22,300 emitted tonnes were generated by road traffic.

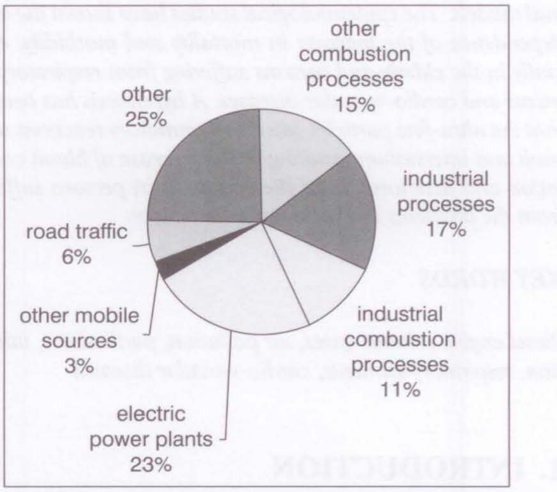

Figure 2 – Primary sources of total dust in Germany

2.3 Spreading of particles

All types of combustion processes (industry, households, traffic) generate ultra-fine particles (nucleus modes) to a smaller or greater extent. On the basis of their diffusion self-mobility they can inter-coagulate, thus forming bigger particulates. The lifecycle of ultra-fine particles ranges from only a fraction of a second to few hours, depending on the concentration of aerosols and thermo-dynamic conditions. When the

Table 1 – Parameters for quantification of exposure to suspended dust

	Designation	Diameter	Anthropogenic sources		Calculation in TSP [20]
			Exterior air	Interior premises	
Total suspended dust	TSP[1]	< 35 μm	whirling up, ind.exhaust, household heating, traffic	whirling up, vacuuming, cooking, smoking	1
Suspended dust that can be inhaled	PM_{10}[1]	< 10 μm	whirling up, ind. exhaust, household heating, traffic	whirling up, vacuuming, cooking, smoking	0.55*TSP
Suspended dust that penetrates lungs	$PM_{2.5}$[1]	< 2.5 μm	ind. exhaust, household heating, traffic	vacuuming, cooking, smoking	$0.60*PM_{10}$ = 0.33*TSP
Ultra-fine particles	$NC_{0.01-0.1}$[2]	< 0.1 μm	ind. exhaust, household heating, traffic	vacuuming, cooking, smoking,	–

[1] measured as concentration of mass in μg/m³ (TSP = total suspended particulates PM = particulate matter)
[2] measured as number concentration in m⁻³ (NC = number concentration)

particles reach a diameter greater than 0.1 μm, their diffusion rate decreases and this may prolong their lifecycle in suspension to several weeks. This area of relatively stable particles of diameter ranging from 0.1 to 1 μm is also designated as accumulation modus. Apart from these fine particles, it is necessary to study also the coarse particles, which e. g. include the whirled up dust and biogenous particles. These particles are deposited by the force of gravity, so that their airborne lifecycle lasts from several minutes to an hour.

Thus, the exposure of people to suspended dust is first of all determined by the following impacts:

- the occurrence of local sources of ultra-fine particles released as result of combustion processes,
- thermodynamic conditions including also meteorological conditions, which apart from creating vapour or fog droplets facilitate coagulation of ultra-fine particles into fine particles or remote transmission of fine particles,
- the processes of surface dispersion which result in the release of coarse particles.

By measuring the particles it has been found that in the number of particles the amount of ultra-fine particles is dominant whereas in the volume – mass the particles above 0.1 μm dominate, which means fine and coarse particles.

It is difficult to determine the characteristics of suspended dust due to the heterogeneity of particulates. In the German air control systems the total mass of suspended dust is determined and expressed as mass (mg or μg) per unit of volume (m^3). Drastic reduction of total suspended dust was recorded in West Germany in the 70s and the 80s and in Eastern Germany since the end of the 80s.

The size of particulates determines whether they can get into the respiratory tract and in which part they will be deposited there. The physical characteristics such as size, density, and the form of particulates, for those bigger than 1 μm are determined by aerodynamic diameter which corresponds to the diameter of ball-shaped particulates of unit density with equal sedimentation characteristics. For very small particles with the diameter smaller than 0.1 μm which are also marked as ultra-fine particles, the thermodynamic diameter is valid, defined as the diameter of unit sphere with equal thermodynamic, i. e. diffusion features. In the transition period between 0.1 and 1 μm the importance of one diameter falls whereas the importance of the other one rises.

2.4 Deposition of particles and clearance from respiratory tract

The probability with which the particulates will be deposited in different lung areas depends on the one hand on their physical properties and on the other hand on the way of breathing and the lung anatomy that changes by growth, as well as age and diseases. In healthy adults and smooth breathing through mouth the majority of particulates of over 5 μm in diameter are dissolved in the oral cavity – pharynx and primary bronchi. Smaller particles do reach the periphery of lungs, and are then dissolved in the secondary bronchi as well as in the bronchioli and alveoli. When breathing through the nose the pattern of disposition changes clearly. The nose filters first of all the big particles (over 2.5 μm) and part of the particles of 1-2.5 μm in diameter.

In different regions of lungs there are different mechanisms for the clearance of foreign bodies. The particles bond over mucous in extrathoracic airways, trachea and the bronchi. In the normal clearance process they are expelled from the respiratory tract within 1 to 3 days. However, the particles may stay in alveolar region longer and may last even for years. Freely moving alveolar macrophages may recognise the particles and phagocyte them as foreign bodies. Efficient phagocytosis occurs especially in case of fine and coarse particles in the range of sizes between 0.3 and 0.5 μm. On the contrary, ultra-fine particles are phagocyted by the alveolar macrophages only to a slight extent and

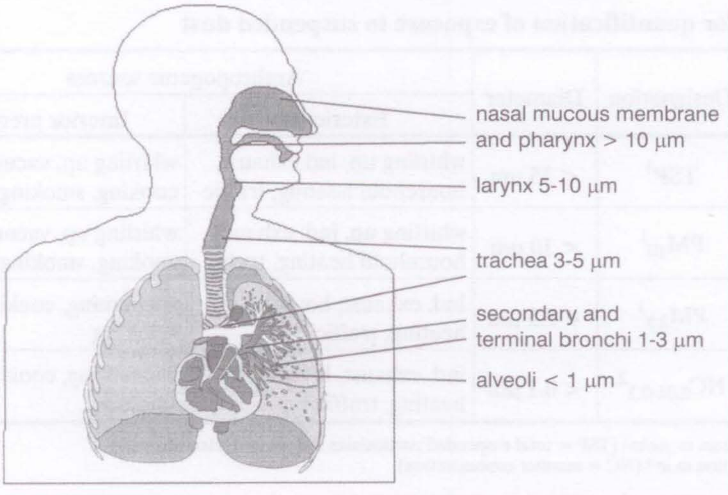

Figure 3 - Penetration of particulates in the respiratory tract

are overtaken to a great extent by the epithelium cells, so that they either stay there or are transferred further into the bonding tissue [3] and [4]

3. HEALTH HAZARDS AND IMPACT ON PEOPLE

3.1. Health hazards

Studies in the field of occupational medicine have first of all indicated the dangerous potential of suspended dust fraction that penetrates the lungs regarding health. The likely existence of negative impacts on health from the concentrations found today in the ambient air could only be confirmed by numerous epidemiological studies.

In the epidemiological studies of the environment the indications have been found on short-term and long-term effects. The results of short-term effects have been summarised by WHO [1] in the following way (quoted in PETERS et al. 1998):

The increase of PM_{10} by 10 μg per m^3 as the daily mean value leads to the increase in mortality by 0.7%, hospital admissions by 0.8%, consumption of medicines in asthmatic patients by 3.4%, increased coughing by 4.6% and lower respiratory tract symptoms by 3.5%. One should start from the linear relation of exposure activity, so that a value that exceeds the threshold cannot be indicated. Few studies have been carried out in Germany and Finland about the short-term effects of ultra-fine particles. It has been proven in asthmatic patients that the symptoms on respiratory tract occur more frequently and the greater Peakflow waste, which in association with the number concentration of ultra-fine particles were stronger than in the association with a mass of fine particles.

From the aspect of long-term action, there have been few studies up to now which studied the action of fine particles. It was found that in the regions with higher concentration of PM_{10} the mortality is increased, the lung function in children is weaker, they suffer more often of bronchial symptoms, and there are more symptoms of chronic bronchitis in adults living in the regions with higher loads of fine dust. The quantification of these effects is even today still difficult.

In the sixties and the seventies the air pollution decreased. However, medical effects could still be proven. Above all [5], [6-9] by means of analyses over a long period, the increase in mortality could be noticed, in case of increased concentrations of harmful substances in the total suspended dust. These results were partly criticised [10], especially the carried out analyses in Philadelphia from 1973 to 1980 [8]. Doubt about the validity of the statistical methods could only be eliminated by independent analyses of the data [11], [12].

At the same time in Europe, it was possible to prove the harmful impact of smog episodes (overview in [13]). The data from the smog episode in 1985 for the Ruhr area showed an increase in mortality, hospital admissions and outpatient treatments compared to a control period. During the smog episode increased number of mortality was found based on cardio-vascular diseases and on respiratory ailments. In this episode it was also indicated that it is suspended dust rather than SO_2 responsible for medical problems. The analysis of the number of mortality in Erfurt about the 80s by SPIX et al. [14]. As part of a European study, the standardised protocol (APHEA: Air Pollution and Health: A European Approach) [15] and [16] was used to analyse the data on mortality from London, Athens, Barcelona and Milan which showed the relation between the harmful components from the air such as SO_2 and "black smoke" and mortality. Only in two cities was the PM_{10} measured or the comparable indicators of pollution of inhalation suspended dust [17] and [18] (s. u.). Starting from these studies and considerations on deposition behaviour of particles, since mid-80s the studies on the action of PM_{10} or fractions with smaller particles have been carried out.

3.2 Impact of ultra-fine particles on health

Studies of the impact of ultra-fine particles on health have been very poor until today. In Erfurt, in winter 1991/92 the distribution of the size of particles was being determined over a period of half a year parallel with the cohort study [49]. In adult asthmatic patients twice as great decrease of Peakflow regarding number concentration of ultra-fine particles was determined as regarding the mass of fine particles [4]. The frequency of symptoms on respiratory tract is also greater with the number of ultra-fine particles than in association with PM_{10}. The data from Kuopi, a town in Finland, did not show any greater effects in asthmatic children in association with ultra-fine particles than with PM_{10} [19].

The particles are not assigned teratogenous or fetotoxic action, but in experiments carried out on animals the inhalation of metal such as arsenic or mercury led to the reduction in the number of the births. In the Czech Republic higher mortality in children was found in the regions with higher air pollution. This was proven by the analyses from the U. S. A. in which the increase in the concentrations of PM_{10} by 20 $\mu g/m^3$ in the first two months of life are statistically significantly related to the increase in the mortality risk by 10% [20]. Besides, in Beijing the indications were gathered about the dependence between the more frequent underweight newborns when higher concentrations were measured in the first quarter [51]. It is still impossible to conclude whether air pollution by harmful substances can result in defect births.

There are no studies on the carcinogenic effects of PM_{10} and $PM_{2.5}$. Indirect indications could be provided by the studies that compare the frequency of cancer in urban and rural areas. A survey [21] indicates relative risk of 1.5 for urban inhabitants compared to inhabitants in rural areas regarding lung cancer. This result relies on the studies which were carried out while studying the smoking behaviour. The possible responsible tiny parts of particulates for this risk under consideration are the metals (arsenic, cadmium, chrome, nickel), polycyclic aromatic hydrocarbons and diesel engine exhaust gases.

3.3. Results of experiments on animals

The complexity of chemical, physical and biological properties of particulates and their versatility aggravates further the estimate of the influence of the suspended dust on the animal model. Most often, the so-called "atmospheric models" are therefore formed, which should facilitate the study of the action of suspended dust on the animal model. It should be noted that the animal model differs from the human model in the lung anatomy and in the clearance mechanisms.

Experimental animals were exposed either in exposure chambers to well characterised particulates that were gathered in the ambient air, or they were instilled intratracheally. Especially dust, containing high concentrations of transition metals caused inflammatory reactions on experimental animals. Special fact of radicals release was identified as the crucial factor for the toxicity of particles. Besides, rats with the pre-existing lung conditions were studied on the impact of concentrated ambient air. Animals with restricted cardio-pulmonary function or with "chronic bronchitis" died in the process. Further, there were indications of bronchoconstriction and inflammation on respiratory tract. These findings were supported by the experiments in which rats suffering from damaged cardio-vascular function were instilled by "fly ash". This led to emphasised inflammatory reactions or to greater mortality.

Special interest is focused at the moment on the research of the action of ultra-fine particles on animals. Thus in TiO_2- particles after instillation, clear inflammatory reaction in interstitium was proved. The reactions were more emphasised in ultra-fine particles than in fine particles. The ultra-fine tephlon particles resulted even in the death of experimental animals within few hours, which was also helped here by the absorbed chemical relations. The basic biological mechanisms were not explained in a satisfactory manner. The deterioration of the medical condition in persons suffering from respiratory ailments, that can result in the increase of the symptoms frequency, increased use of medicines, increased usage of hospital admissions, and in individual cases can cause even death, may be explained by the induction of bronchoconstriction and inflammatory reaction in lungs. Currently the hypothesis is being discussed that ultra-fine particles cause inflammatory reactions in alveoli and in interstitium with greater blood coagulation thus resulting in deterioration of the condition in persons suffering from cardio-vascular system diseases. This hypothesis could be proven in the meantime in several studies.

GODLESKI et al. [21] showed on rats with pulmonary problems (chronic bronchitis induced by exposure to high concentration of SO_2 during a period of over 6 weeks or acute pneumonia induced by the installation of monocrytoline) the action of particles from the Bostonian ambient air (Table 2). The animals were for 3 days exposed to harmful substances

Table 2 - Results of inhalation experiments on rats after exposure to 230 – 290 μg/m³ $PM_{2.5}$ over 3 days (according to GODLESKI et al. [21]

	Control	right-sided heart insufficiency	chronic bronchitis
mortality	0%	19%	37%
autopsy results			
inflammatory reactions	none	in alveoli and interstitium	in respiratory system, increased mucus
bronchoconstrictions	none	moderate	high
oedemas	none	none	interstitium

between 230 to 290 $\mu g/m^3$ $PM_{2.5}$ made by saturation of particles in approximately 10-times concentration. Whereas healthy rats during autopsy did not either die or show signs of inflammatory reactions on their respiratory tracts, 19% of rats with clearly limited cardio-pulmonary function and 37% with chronic bronchitis died. The signs of bronchoconstriction and inflammation of respiratory tract were found in both "disease models". Generally, the action of particles was more emphasised in rats with chronic bronchitis. There were no deaths when the animals remained in clean air. These findings were supported by the experiments in which the rats with limited cardio-vascular function were instilled by an increasing concentration of "fly ash" (0.25 mg to 2.5 mg per animal). Depending on the exposure and the emphasised inflammatory reactions the increase in mortality within a period of 96 hours was noted. Besides, the studies underline the role of the soluble transition metals during the induction of inflammatory processes.

The hypothesis has been set that maybe apart from chemical properties of particles, the number concentration of particles was co-responsible for the observed patophysiologic processes. In the experiment with TiO_2- particles that are considered to be inert OBERDORSTER et al [22] showed that the instillation of ultra-fine particles (500 μg with 20 nm diameter) caused higher concentration of particles in the interstitium and more obvious inflammatory reactions than the instillation of fine particles (500 μg with 250 nm diameter). In one inhalation experiment with TiO_2- particles, the rats were exposed to high concentrations (23.5 mg/m^3 at 20-nm-particles and 22.3 mg/m^3 at 250-nm-particles) for six hours a day, five days a week over 12 weeks. The restriction should be mentioned here that in these high concentrations of aerosol the ultra-fine particles were agglomerated into fine particles in the range between 0.2 – 0.5 μm. Nevertheless, clearly more emphasised inflammatory reactions with ultra-fine particles were indicated than with fine particles, and higher concentrations of particles in the interstitium were found in case of the exposure to ultra-fine particles. This may be interpreted in the way that the deposited agglomerates of particles disintegrate into their primary components, so that ultra-fine portions are less efficiently absorbed than the alveolar macrophage but more strongly than the epithelium cells. The attention was drawn by the study in which the rats were exposed for 20 to 30 minutes to ultra-fine particles (40-60 $\mu g/m^3$, 26 nm in diameter, numeric concentration: 0.7-1.0*10 particles per cm^3). This exposure resulted in the death of all the experimental animals within 4 hours. The cause was acute hemorrhagic pulmonary oedema with massive inflow of leukocytes and subsequent failure of lungs and heart. Toxic reactions of this nature from poisoning by polytetrafluoroethylene smoke are known in medicine under the name of polymeric smoke fever. Detailed biochemical and molecular - biological researches have confirmed the inflammatory processes that can be caused by ultra-fine Teflon particles. It is important to note that the Teflon particulates are not particulates from the ambient. A large area of ultra-fine particles represents an ideal transport means for the toxic substances into the lungs.

3.4. Evaluation of the threat potential

3.4.1. Quality evaluation

Generally it may be concluded that the relative risks related to the increased load of the pollutants in the air are small but still affect the mortality and morbidity of the overall population. The role of other pollutants in the air which act together with the particulates, such as e. g. SO_2 and O_3 are still being researched. It seems certain that in the areas in which there are gaseous pollutants in concentrations greater than the today's marginal value, they contribute to the observed harmful impact. It is not to be excluded that the effects of the gaseous harmful substances are overestimated since their quantification is carried out in a more accurate manner. The most convincing point of reference that the particulates even without gaseous harmful matter in the air represent threat to health has been found in the Utah Valley. This region is distinguished by the absence of SO_2 and O_3 at simultaneously moderate PM_{10}-concentrations. Even under these conditions the effect of ambient aerosols could be proven, measured as PM_{10}, on the mortality and

Table 3 – Marginal values, guidelines, recommendations for protection of people

			particulates	
air				
workplace				
East Germany	MAK – list	1997	1.5 mg/m^3 R	8 h (fine dust)
			3 mg/m^3 R	marginal limit
			4 mg/m^3 I	8 hours (total dust)
			8 mg/m^3 I	marginal limit
exterior air				
Germany	MIK values	1992	75 $\mu g/m^3$ SST	annual mean value (airborne dust)
			250 $\mu g/m^3$ SST	24 h
			150 $\mu g/m^3$ SST	24 h – on consecutive days
			500 $\mu g/m^3$ SST	1 h in up to 3 consecutive days
	22 BImschV	1994	150 $\mu g/m^3$ SST	annual mean value
			300 $\mu g/m^3$ SST	95 percentile (year)
	TA Luft	1986	150 $\mu g/m^3$ SST	annual mean value
			300 $\mu g/m^3$ SST	98 percentile of midday
EU	Guidelines	1989	150 $\mu g/m^3$ SST	annual mean value
			300 $\mu g/m^3$ SST	95 percentile of midday
	concept	1997	30 $\mu g/m^3$ PM_{10}	annual mean value (from 2005)
			20 $\mu g/m^3$ PM_{10}	annual mean value (from 2010)
			50 $\mu g/m^3$ PM_{10}	24 hour, 96 percentile (from 2005)
			50 $\mu g/m^3$ PM_{10}	24 h, 98 percentile (from 2010)
			19 $\mu g/m^3$ $PM_{2.5}$	annual mean value (from 2010)
			38 $\mu g/m^3$ $PM_{2.5}$	24 h, 98 percentile (from 2010)
US	EPA	1997	50 $\mu g/m^3$ PM_{10}	annual mean value
			150 $\mu g/m^3$ PM_{10}	24 h
			15 $\mu g/m^3$ $PM_{2.5}$	annual mean value
			65 $\mu g/m^3$ $PM_{2.5}$	24 h
WHO Air Quality Guidelines		1996	120 $\mu g/m^3$ SST	24 h (total dust)
			70 $\mu g/m^3$	24 h (inhaled dust)
indoor rooms			–	
soil			–	
water			–	
food			–	
total			–	
special properties of material			–	
unit risk				
WHO Air Quality guidelines		1996	10 $\mu g/m^3$ PM_{10}	
			10 $\mu g/m^3$ $PM_{2.5}$	

R: dust that reaches the alveoli = fine dust PM_{10}: mass of particles > 10 μm in diameter
I: dust which can be inhaled = total dust $PM_{2.5}$: mass of particles > 5 μm in diameter
SST: suspended dust gravimetric method
MAK-list: (maximal concentrations at workplace) by DFT, Deutsche Forschungsgemeinschaft
MIK: values of maximum concentrations of imissions from guideline 2310 VDI, Verein Deutscher Ingenieure
BImschV: Bundesimmissionsschutzverordnung, government regulation on immission protection
TA Luft: Technische Anleitung zur Reinhaltung der Luft, Technical instructions on maintaining clean air
EPA, United States Environment Protection Agency

morbidity of the population [23]. In spite of everything, it remains to be identified which physical, chemical and biological properties of particulates are responsible for the observed effects on health.

3.4.2. Quantity evaluation

Based on the mentioned results of epidemiological studies it is possible to evaluate the medical effect of increased particulates. The research e. g. studied what are the effects when the load is greater than 50 $\mu g/m^3$ or 100 $\mu g/m^3$ with PM_{10}.

This led to the introduction of stricter marginal values for PM_{10} (150 $\mu g/m^3$ 24 h-value) and $PM_{2.5}$ (65 $\mu g/m^3$ 24 h-value) in environmental protection, especially in the U. S. A. The EU has been following these guidelines.

Regarding the threat from ultra-fine particles no conclusive statements are possible at the moment. Experiments on animals and epidemiological warnings of specific impact of ultra-fine particles should lead to greater attention. This refers to the measurement control of the number of particulates or the area, as well as more intense scientific efforts in explaining the phenomenon.

3.4.3. Marginal values / reference values / recommendations

Up to now, in Germany there have been only marginal and reference values for the overall suspended dust (Table 3). In the U. S. A. the following marginal values for PM_{10} have been valid since 1987: for daily mean values the maximum is 150 $\mu g/m^3$. Since July 1997 an additional act came into force which predicts reduction of 24-hour mean value of $PM_{2.5}$ to 65 $\mu g/m^3$ (98 percentile is not to exceed this value within 3 years) and annual mean value of 15 $\mu g/m^3$ $PM_{2.5}$ is stipulated as the upper limit. The new issue of „Air Quality Guidelines for Europe" has not been published yet, but the recommendations have already been determined. There will be no instructions mentioned for PM_{10} or $PM_{2.5}$ since the data available do not allow publication of concentrations below which the impact cannot be expected. The impact on mortality and morbidity in 24-hour concentrations has been measured clearly below 100 $\mu g/m^3$ (PM_{10}) and in annual mean values below 20 $\mu g/m^3$ ($PM_{2.5}$) or 30 $\mu g/m^3$ (PM_{10}). For the overall suspended dust the old recommendation has remained – 24-hour concentration of 120 $\mu g/m^3$. The old marginal values for suspended dust are still valid within the European Union. From 2005, the introduction of marginal values for PM_{10} and from 2010 for $PM_{2.5}$ [2] and [24] (Table 3) are predicted in compliance with the existing draft of the European Commission.

4. CONCLUSION

Diesel particles consist of a large number of substances and they change on their way from the engine to the inhalation by men. The processes that occur on the way, e. g. condensation of sulphates and hydrocarbons on the particle nuclei depend, among other things, on the temperature and concentration of the considered substances. During their long stay in the atmosphere, the Diesel particles can bond i. e. they can react with the substances from other sources. The drive dynamics factor cannot be taken into consideration. Therefore, the precise definition of diesel particles is significant. The standard procedure of measurement on the testing device is used to define the mass of particles from the solid and liquid components of exhaust gases which are separated at 52°C on the test filter with exhaust gases diluted by the ambient air. The mass of particulates consists to a significant extent of the soluble organic hydrocarbons and elementary carbon (EC) and a number of other substances (e. g. sulphate). The share of different fractions depends on the engine concept, driving characteristics of the sizes, system of subsequent final processing of exhaust gases and fuel characteristics.

By preventing exposure the individual precautionary measures are only partly efficient in the outdoor air since the fine particles penetrate to a great extent indoors. Single precautionary measures regarding fine particles are also not possible. Thus also the cellulose masks that are partly worn in the regions with smog do not provide efficient protection. Targeted reductions in the emission of dust generated by the fuel combustion in engines (industry, household and traffic) are necessary. Apart from reducing the concentration of the mass of fine particles it is necessary to reduce the number concentration of ultra-fine particles in the atmosphere.

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SAŽETAK

UTJECAJ ISPUŠNIH PLINOVA DIESEL MOTORA NA ONEČIŠĆENJE OKOLIŠA I LJUDSKO ZDRAVLJE

Fine čestice , koje se nalaze u ispušnim plinovima dizel motora , s promjerom od 2.5 μm i ultra-fine čestice s 0.1 μm promjera pretežito potječu iz procesa izgaranja. Pokusi na

životinjama pokazali su da čestice iz vanjskog zraka posjeduju mogućnost izazivanja oštećenja pluća pa i smrt. Iz tog razloga potrebno je smanjiti masu finih čestica u atmosferi i reducirati broj ultrafinih čestica. Brojne studije o pokusima na životinjama pokazale su toksičnost navedenih čestica. Zrak obogaćen s česticama doveo je do kardiopulmonalnog oboljenja na životinjskim modelima. Epidemiološke studije pokazale su povezanost porasta mortaliteta i morbiditeta , posebno kod starijih ljudi i kod osoba s oboljenjem dišnih putova i kardiovaskularnim oboljenjem. Postavljena je hipoteza da ultrafine čestice izazivaju upalne reakcije u alveolama i intersticiju i dovode do porasta koagulacije krvi i do pogoršanja stanja kod osoba s oboljenjem kardiovaskularnog sustava.

KLJUČNE RIJEČI

ispušni plinovi dizel motora, zagađenje zraka, čestice, inhalacija, bolesti dišnih putova, kardiovaskularna oboljenja

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