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Bij beantwoording datum, onze referentie en onderwerp vermelden.

Datum 20-12-2019
Onderwerp Besluit op uw Wob-verzoek

Geachte heer [redacted]

Bij brief van 4 oktober 2019 heeft u een verzoek ingediend als bedoeld in artikel 3, eerste lid, van de Wet openbaarheid van bestuur (Wob). U verzoekt om het TNO-onderzoek V20323, 'Particulate matter current guidelines and application in risk assessment'.

Ik besluit TNO-onderzoek V20323 openbaar te maken.

Daar waar in het onderzoeksrapport persoonsgegevens zijn vermeld, zijn die met toepassing van artikel 10, tweede lid, onder e, van de Wob (eerbiediging van de persoonlijke levenssfeer) onleesbaar gemaakt. In die gevallen heb ik het belang van privacy (van betrokkenen) laten prevaleren boven het belang van openbaarmaking, waarbij ik heb overwogen dat de persoonsgegevens niet daadwerkelijk toevoegen aan de inhoud het onderzoeksrapport.

Ik vertrouw erop u hiermee voldoende te hebben geïnformeerd.

Hoogachtend,

De Minister van Defensie
voor deze
De Secretaris-Generaal,

[redacted]

mr. G.E.A. van Craaikamp

[redacted]

Belanghebbenden kunnen binnen zes weken na bekendmaking van dit besluit bezwaar indienen bij de Minister van Defensie. Het bezwaarschrift dient te worden gericht aan DienstenCentrum Juridische Dienstverlening, Commissie advisering bezwaarschriften Defensie, Postbus 90004, 3509 AA Utrecht. Het bezwaarschrift moet zijn ondertekend, een dagtekening bevatten en van de naam en het adres van de indiener zijn voorzien. Uit het bezwaarschrift moet duidelijk blijken tegen welk besluit en op welke gronden bezwaar wordt gemaakt.

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TNO Triskelion report

V20323 | Final |

Particulate matter current guidelines and application in risk assessment

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Table of content

1. Introduction

In a previous report prepared by TNO Triskelion within WP200 (final draft version provided on 16-04-2012), a thorough study has been performed on possible health effects caused by several air pollutants, including particulate matter (PM_{10} and $PM_{2.5}$) focusing on the exposure of military personnel. In this report, we evaluate the current guidelines concerning particulate matter and determine which of these guidelines would apply to military personnel and whether existing guidelines should be modified to be applicable to military personnel. Therefore, the set-up and (scientific) rationale of the different guidelines was evaluated.
In the future, it may be relevant to also include limits or guidelines for even smaller particle sizes, e.g. $PM_{1.0}$ or nanoparticles (*i.e.* particles with a size below 100 nm in at least one dimension). However, limits for these types of dusts are still very much in development and they have not been included in this document.

2. Current limit values (WHO, EU, USEPA, and USPHC) for Particulate Matter

2.1 General

Several guidelines have been proposed over the recent years to determine the maximum concentrations of particulate matter to which humans should be exposed. All the different guidelines proposed are recommended by a group of experts reviewing the available scientific research and when necessary taking other factors such as cost benefits, background levels, and technological feasibility into account. The general consensus is that adverse effects on health due to particulate matter cannot be entirely ruled out below any value and therefore quantitative risk assessment offered a way to estimate the residual risk associated with a particular guideline value. In the next paragraphs four different guidelines on particulate matter are described.

2.2. World Health Organization (1, 2)

In 1987, the World Health Organization (WHO) proposed their first Air Quality Guidelines (AQGs) in order to provide national governments with targets for air quality management to reduce air pollution-induced health effects. These guidelines were updated in 1997 and in 2005. Furthermore, they introduced Interim Targets (IT). The WHO considers these targets to be achievable with successive and sustained abatement measures and countries may find these interim targets particularly helpful in gauging progress over time in the process of steadily reducing population exposures to PM. All these WHO guidelines were recommended by a working group consisting of experts in toxicology, epidemiology, air quality exposure assessment, air quality management, and public policy and their advice was reviewed by external reviewers from relevant disciplines and all together during the Working Group on Air Quality Guidelines in Bonn, 18-20 October 2005, guidelines were discussed and finalized.

In 2005, the annual mean for $PM_{2.5}$ and PM_{10} were set at 10 and 20 $\mu g/m^3$, respectively, while the 24-hour mean was set at 25 and 50 $\mu g/m^3$ for $PM_{2.5}$ and PM_{10}, respectively. Besides the guidelines, three ITs were defined for both long-term (Table 1A) and short-term exposures (Table 1B) to indicate the increased long-term mortality risk at higher particulate matter concentrations. The annual average of 10 $\mu g/m^3$ for $PM_{2.5}$ was chosen since it represented the lower end of the range over which significant effects on survival have been observed in the long-term exposure studies using the American Cancer Society Study (ACS) and Harvard Six-Cities data (3, 4, 5, 6, 7). In these studies, robust associations were reported between long-term exposure to $PM_{2.5}$ and mortality. The working group noted that thresholds were not observed in these studies, however, in the ACS study, statistical uncertainty in the risk estimates became apparent at concentrations of about 13 $\mu g/m^3$, below which the confidence bounds significantly widen since the concentrations are relatively far from the mean. Furthermore, it was observed in the study of Dockery *et al.*, that the risks were similar in the cities at the lowest long-term $PM_{2.5}$ concentrations of 11 and 12.5 $\mu g/m^3$ (3). Increases in risk were observed in the city with the next-lowest long-term $PM_{2.5}$ mean of 14.9 $\mu g/m^3$, indicating likely effects in the range of 11 to 15 $\mu g/m^3$. Therefore, the workgroup concluded that an annual concentration of 10 $\mu g/m^3$ would be below the mean of the most likely effects levels indicated in the available literature. Furthermore, they put some weight on daily exposure time-series studies examining relationships between $PM_{2.5}$ and acute adverse health outcomes. These studies have long-term (three- to four-year) means in the range of 13 to 18 $\mu g/m^3$. The documentation indicates the different susceptibility of subpopulations. The developed guidelines are for the whole population, including these susceptible subpopulations.

Table 1A: WHO air quality guidelines (AQG) and interim targets (IT) for particulate matter: annual mean concentrations.

	PM_{10} ($\mu g/m^3$)	$PM_{2.5}$ ($\mu g/m^3$)	**Basis for selected level**
IT-1	70	35	15% higher long-term mortality risk compared to AQG
IT-2	50	25	Lower the risk of premature mortality by approx. 6% compared to IT-1
IT-3	30	15	Reduces the mortality risk by approx. 6% compared to IT-2
AQG	20	10	These are the lowest levels at which total, cardiopulmonary and lung cancer mortality have been shown to increase with more than 95% confidence in response to long-term exposure to $PM_{2.5}$.

Table 1B: WHO air quality guidelines (AQG) and interim targets (IT) for particulate matter: 24-hour concentrations.

	PM_{10} ($\mu g/m^3$)	$PM_{2.5}$ ($\mu g/m^3$)	**Basis for selected level**
IT-1	150	75	About 5% increase in short-term mortality over the AQG value.
IT-2	100	50	About 2.5% increase in short-term mortality over the AQG value.
IT-3	75	37.5	About 1.2% increase in short-term mortality over the AQG value.
AQG	50	25	Based on relationship between 24-hour and annual PM levels.

2.3. European Union

Over the years, the European parliament and the Council came with directives concerning ambient air quality and set values to which Member States of the European Union should comply. The EU guidelines are divided into two categories; limit values, which is a level to be attained within a given period and not to be exceeded once and target values which is a level to be attained where possible over a given period. The deadline to meet the PM_{10} limit values was 1 January 2005. The deadline for meeting the $PM_{2.5}$ target value was 2010 and the limit values for $PM_{2.5}$ need to be reached in 2015 (25 $\mu g/m^3$) and 2020 (20 $\mu g/m^3$). For PM_{10} there are limit values for short-term (24 hours) and long-term (annual) exposure, while for $PM_{2.5}$ there are only values for long-term exposure.

European guidelines are also based on recommendations from working groups. In 1997, the Technical Working Group on Particles set up by the European Commission and consisting of experts from different countries, came up with an advice on guidelines concerning limit values for PM_{10} (8). Based on the available evidence, and taking into consideration that without an effect threshold, no values can be proposed on a scientifically sound basis, they recommended that the PM_{10} 24-hour average concentration limit value should be set within the range of 30-100 $\mu g/m^3$ and the annual mean concentration within the range of 15-40 $\mu g/m^3$. Eventually the values were set at 50 and 40 $\mu g/m^3$, respectively. In 2004 a revision was made on the previous guideline based on a report of the CAFE Working Group on Particulate Matter (9). Based on the advice from WHO, $PM_{2.5}$ instead of PM_{10} was selected as indicator to assess particulate matter related health effects. They concluded that exposure to fine particulate matter should be reduced up to the lower end of the concentration range investigated in the ACS study (6). They stated that further reduction of total population exposure is needed, but they also took other factors into account like current particulate matter levels, natural background concentrations, attainability and cost-benefits when establishing legally binding limit values. Since already a decreasing trend in fine particulate matter concentrations in air was observed they advised that by 2010 a limit value of 20 $\mu g/m^3$ should be reached. However, they also stated that no single particulate matter level should be recommended at this time. Rather, values within the range 12 to 20 µg/m3 should be used as an input to the integrated assessment procedure. From the available, but scarce information on the frequency distribution of 24-hour values, the majority of the working group recommended that a 24-hour average limit value for $PM_{2.5}$

around 35 µg/m^3 (not to be exceeded more than 10% of the days of the year) seems reasonable as a starting point from which eventually further reductions could be made.
The European Union, in Directive 2008/50/EG presented the conclusions that were reached in the form of limit values, target values and 'exposure concentration obligations', which are three-year average values. These values, like those from the WHO, are for the whole population, including the susceptible subpopulations. The limit values from Directive 2008/50/EG are presented in Table 2.

Table 2: European air quality limit and target values for PM_{10} and $PM_{2.5}$ (10, values from Directive 2008/50/EG)

Size Fraction	Average period	Value (µg/m^3)	Comments
PM_{10}, limit value	One day	50	Not to exceed on more than 35 days per year. To be met by 1 January 2005
PM_{10}, limit value	Calendar year	40	To be met by 1 January 2005
$PM_{2.5}$, limit value	Calendar year	25	To be met by 1 January 2015
$PM_{2.5}$, limit value	Calendar year	20	To be met by 1 January 2020

2.4. USA (USEPA)

In the USA, the US Environmental Protection Agency (USEPA) set their first particulate matter standards, better known as the National Ambient Air Quality Standards (NAAQS), in 1987. The 24-hour PM_{10} standard was set at 150 µg/m^3 with no more than one expected exceedance per year and an annual PM_{10} of 50 µg/m^3 was set. In 1997, $PM_{2.5}$ limit values were set. The annual standard was set at a level of 15 µg/m^3, based on the 3-year average of annual arithmetic mean $PM_{2.5}$ concentrations. The 24-hour standard was set at a level of 65 µg/m^3, based on the 3-year average of the 98th percentile of 24-hour $PM_{2.5}$ concentration. In 2006, the 24-hour standard was revised and set at 35 µg/m^3 (11).

Also the USEPA proposed standards for particulate matter were based on a thorough review of the current scientific evidence. The greatest weight was placed on the long-term means of the concentrations associated with mortality effects in two long-term exposure studies; the ACS and Harvard Six Cities studies. For setting the 24-hour $PM_{2.5}$ standard to 35 µg/m^3, the greatest weight was placed on epidemiological evidence from U.S. and Canadian short-term $PM_{2.5}$ exposure studies. Although, no threshold was observed in these studies, and therefore a standard level was chosen that would require improvements in air quality generally in areas in which the distribution of daily short-term $PM_{2.5}$ concentrations could reasonably be expected to be associated with serious health effects (11).

The USEPA also maintains a standardized Air Quality Index (AQI), set in 1999, where for any given 24-hour exposure level a possible effect is predicted and recommendations are given how the general population should act (Table 3) (12). The statements with the AQI do give specific recommendations for sensitive individuals or susceptible subpopulations.

Table 3: Air Quality Index (12) (24 hr)

AQI Category	PM (µg/m3) $PM_{2.5}$	PM_{10}	Statement
Good	0-15	0-50	
Moderate	>15-40	>50-150	Respiratory symptoms possible in unusually sensitive individuals, possible aggravation of heart or lung disease in people with cardiopulmonary disease and older adults. Unusually sensitive people should consider reducing prolonged or heavy exertion.
Unhealthy for sensitive groups	>40-65	>150-250	Increasing likelihood of respiratory symptoms in sensitive individuals, aggravation of heart or lung disease and premature mortality in people with cardiopulmonary disease and older adults. People with heart or lung disease, older adults, and children should reduce prolonged or heavy exertion.
Unhealthy	>65-150	>250-350	Increased aggravation of heart or lung disease and premature mortality in people with cardiopulmonary disease and older adults; increased respiratory effects in general population. People with heart or lung disease, older adults, and children should avoid prolonged or heavy exertion; everyone else should reduce prolonged or heavy exertion.
Very unhealthy	>150-250	>350-420	Significant aggravation of heart or lung disease and premature mortality in people with cardiopulmonary disease and older adults; significant increase in respiratory effects in general population. People with heart or lung disease, older adults, and children should avoid all physical activity outdoors. Everyone else should avoid prolonged or heavy exertion.
Hazardous	>250-500	>420-600	Serious aggravation of heart or lung disease and premature mortality in people with cardiopulmonary disease and older adults; serious risk of respiratory effects in general population. Everyone should avoid all physical activity outdoors; people with heart or lung disease, older adults, and children should remain indoors and keep activity levels low.

2.5. USA (USPHC) (13, 14)

The US Army Public Health Command (USPHC) proposed in 2010 Military Exposure Guidelines (MEG) concerning particulate matter. They set guideline values and indicated which health effects could be observed at any given level, stating that below 15 µg/m^3 (annual) and 65 µg/m^3 (24-hour), negligible effects would be observed in generally healthy troops (Table 4).

Their MEGs are based on the NAAQS and the AQI as proposed by the USEPA. There are however some differences and the assumption is made that troops are less susceptible to long-term health effects from $PM_{2.5}$ exposures compared to the general population. The NAAQS are designed to protect the general population, but since no study is available that specifically investigate the long-term health consequences of $PM_{2.5}$ exposures in healthy adults; the annual $PM_{2.5}$ of 15 µg/m^3 set by USEPA was also used for the long-term Negligible MEG (*i.e.* the value at which negligible effects would be observed). The USAPHC also modified the AQI sub-index categories to define acute hazard severity of the deployed population at certain PM concentrations. For the annual MEGs, professional judgment reflecting a consensus opinion of USAPHC subject matter experts set a Marginal MEG (a value at which only marginal effects would be observed) for $PM_{2.5}$ at 65 µg/m^3, which is the AQI threshold for "Unhealthy" exposures. This Marginal MEG represents an estimated point of demarcation for a higher degree of plausible risk for long-term health effects amongst troops continuously exposed to such PM levels.

For the 24-hour $PM_{2.5}$ MEG, USPHC stated that the direct use of the 24-hour NAAQS was inappropriate because it would be too conservative in the context of military deployments. The 24-hour Negligible MEGs were set to the threshold where healthy individuals in the general population are expected to start experiencing effects. They however conclude that the level of protection provided by the 24-hour PM MEGs is uncertain due to a lack of directly relevant data and the limitations of the available data. The MEGs proposed by the USPHC are aimed at individuals that are in principle healthy adults, although it is considered that even deployed personnel could have a small proportion of more susceptible individuals.

Table 4A: Annual (long-term) particulate matter MEGs proposed by the USPHC.

Hazard severity	$PM_{2.5}$ ($\mu g/m^3$)	PM_{10} ($\mu g/m^3$)	Description of Military Health and Operational Effects
Marginal	65	Not defined	With repeated exposures above this, it is plausible that development of chronic health conditions such as reduced lung function or exacerbated chronic bronchitis, COPD, asthma, atherosclerosis, or other cardiopulmonary diseases could occur in generally healthy troops. Those with a history of asthma or cardiopulmonary disease are considered to be at particular risk. This guideline is an uncertain screening value. It is not a known health effects concentration.
Negligible	15	Not defined	With repeated exposures above this, it is considered possible that a small percentage of personnel may have increased risk for developing chronic conditions such as reduced lung function or exacerbated chronic bronchitis, COPD, asthma, atherosclerosis, or other cardiopulmonary diseases. Personnel with history of asthma or cardiopulmonary disease are considered to be at particular risk. Exposures below this are not expected to result in development of chronic health conditions in generally healthy troops.

Table 4B: 24 Hour (short-term) particulate matter MEGs proposed by the USPHC. Adapted by USPHC technical guide

Hazard severity	$PM_{2.5}$ ($\mu g/m^3$)	PM_{10} ($\mu g/m^3$)	Description of Military Health and Operational Effects
Critical	500	600	Above these, most if not all personnel will experience very notable eye, nose, and throat irritation and respiratory effects. Visual acuity is impaired, as is overall aerobic capacity. Some personnel will not be able to perform assigned duties. Some lost-duty days are expected. Those with a history of asthma or cardiopulmonary disease will experience more severe symptoms.* Conditions may also result in adverse, non-health related materiel/logistical impacts
Marginal	250	420	Above these, a majority of personnel will experience notable eye, nose, and throat irritation and some respiratory effects. Some lost-duty days are expected. Significant aerobic activity will increase risk. Those with a history of asthma or cardiopulmonary disease are expected to experience increased symptoms.*
Negligible	65	250	Above these, a few personnel may experience notable mild eye, nose, or throat irritation; most personnel will experience only mild effects. Pre-existing health conditions (e.g., asthma, or cardiopulmonary diseases) may be exacerbated.*

* Diagnosis of pulmonary or cardiopulmonary diseases would prevent deployment, though some conditions may go undetected. A small percentage of deployed personnel fall into this sensitive group.

2.6. Worker exposure limits

There are no Dutch worker exposure limits for either PM_{10} or $PM_{2.5}$. Traditionally, worker exposure limits have been established for 'inhalable' (sometimes called 'total') and 'respirable' dust. These dust fractions are defined by sampling characteristics providing the percentage of certain sizes of particles to be sampled. The definition of the sampling characteristics for respirable dust includes a 50% sampling efficiency for particles with an aerodynamic diameter of 4 µm. A respirable dust sampler will also sample larger particles, e.g. 5% of the particles with an aerodynamic diameter of 8 µm. For inhalable dust samplers the definition includes a 65% sampling efficiency for particles with an aerodynamic diameter of 20 µm (17).

The Dutch 'Socio Economic Council' on its webpage[1] maintains an Occupational Exposure Limit database that reports the following values for inhalable and respirable dust:

- Inhalable dust: 10 mg/m^3 (valid in several countries, including USA, France and Germany); until the change in the system of limit values in The Netherlands at the start of 2007, this was also the Dutch occupational exposure limit;
- Respirable dust: 3 mg/m^3 (valid in several countries, including Germany, Belgium and Spain) or 5 mg/m^3 (valid in other countries, including USA, France and Sweden).

More recently, generic guidelines have been set in several countries for worker exposure to smaller particles, such as PM1.0 and nanoparticles. However, these are not yet sufficiently hazard based.

[1] http://www.ser.nl/en/oel_database.aspx

3. Considerations for military personnel

The guidelines and limit values described above apply to the general population, with exception of the MEGs. Certain populations however could be less susceptible to particulate matter compared to the general population. For instance, healthy young persons might be better able to cope with exogenous exposure compared to elderly. Furthermore, deployed military personnel could be exposed to different PM concentrations and different particle composition of the PM compared to the general population. Also, military personnel may have a rather different exposure pattern than the general worker population or the general population. When deployed, their working hours can be more than 8 hours per day. Also, they may have a relatively high physical activity pattern, leading to a higher inhalation rate. And finally, they may be deployed in specific locations that have specific features compared to the locations of the general population and workers for which the present exposure limits have been set, e.g. in desert areas with a high contribution of crustal particles in the dust. Therefore, it was determined if the current guidelines would also apply to military personnel and whether these limit values should be adjusted.

3.1. Susceptibility of a healthy population

There are several different factors known in the literature which affect ones susceptibility to exogenous exposure including genetic background, race, gender, age, lifestyle (e.g. smoking, alcohol consumption and nutrition) or preexisting diseases. Identifying the specific risk factors will allow the possibility to come up with a more specified risk assessment.

A number of articles have been published which divided their results into subpopulations. The USEPA has reviewed available literature concerning population susceptibility to particulate matter and analyzed several of the factors mentioned above in their report of 2010 (11). From the literature, it was concluded that older adults represent a potentially susceptible population due to the higher prevalence of pre-existing cardiovascular and respiratory diseases found in this age range compared to younger age groups. The USEPA also concluded from epidemiologic studies that children are more susceptible to particulate matter, which could be a result of the developing lung being more susceptible to particulate matter. Gender and ethnicity on the other hand appear not to have an effect on increased susceptibility. The USEPA also concluded that the evidence from epidemiologic and toxicological, and to a lesser extent, controlled human exposure studies indicate an increased susceptibility of individuals with underlying cardiovascular diseases and respiratory illnesses, specifically asthma, to particulate matter exposure.

3.2. Particle composition and exposure

Another difference between the general population and military personnel is the type of particulate matter to which these two populations are exposed. Fossil-fuel combustion is the predominant source of particulate in areas with high population density, however, in some deployed settings; dust storms can be a major contributor to the total PM concentration (14). In a study performed by Laden *et al.*, the association between mortality and $PM_{2.5}$ from different sources was determined in six US cities (15). It was concluded that $PM_{2.5}$ crustal particles (particles originating from the earth crust and therefore largely sand related) were not associated with daily mortality. In a study by Mar et al who investigate the relation between air pollution and mortality in Phoenix between 1995 and 1997, a negative association was found between soil and mortality (16). It can therefore be concluded that the possible increased exposure to $PM_{2.5}$ in deployment settings due to for instance sand storms is less adverse compared to $PM_{2.5}$ particles derived from fuel combustion. The studies that indicated a lower effect from crustal particles were not based on the very high exposure levels to crustal particles that may occur in some desert areas.

Although several groups that have set guidelines for exposure to particulate matter have acknowledged the potential for different effects from different types of particles, all guidelines have been developed for 'general particulate matter'. Due to the fact that most studies have been done in industrialized areas, the basis of the guidelines is more related to particulate matter with a high contribution of fossil fuel emission particulates than to particulate matter that largely consists of crustal particles.

3.3. Working hours and inhalation rate

Deployed military personnel may have longer than usual working hours (more than 8 hours per day). However, when the limits for military personnel are based on general population limits, this will not lead to an underestimation of risk, because general population limits are usually set for 24 hours.
The limits set by different groups do not indicate any modification needed for higher inhalation rates. Deployed military personnel can be expected to often have a relatively high inhalation rate and therefore may inhale more dust than the general population. This leads to some uncertainty regarding the appropriateness of military limits based on general population limits.

4. Conclusion

The aim of this report is to identify guidelines for the exposure of military personnel to particulate matter. The WHO, USEPA, and EU determined annual guideline/limit values for exposure to particulate matter ($PM_{2.5}$) of 10, 15 and 20 $\mu g/m^3$ for the general population, respectively. Since military personnel are relative young and healthy and therefore less susceptible to particulate matter, the question was raised if the proposed values for the general population could not be adjusted for the specific population.

Both the WHO and the EU do not take specific subgroups into account in their determination of guidelines or limit values. However, the USEPA introduced the AQI, where for any given 24-hour exposure level a possible effect is given. These values were set for the general population, but a distinction was made between sensitive and healthy individuals. The USPHC used these values to propose guidelines for healthy military personnel by excluding the levels set for sensitive individuals.

In conclusion, there is insufficient information regarding the difference in effects for healthy adults compared to the general population to allow a quantitative recalculation from guideline values for the general population to specific values for military personnel. Furthermore, no specific guideline values for dusts that consist for a large part of minerals from the earth crust can be derived, because of a lack of quantitative information on the difference in effects of crustal particles and other particles. Similarly, there is no quantitative information on the effect of a higher inhalation rate on the effects of dust.
However, the USPHC values were set for a generally healthy military population and the use of these values would therefore not be affected by the uncertainties in extrapolation from general population values. We therefore recommend using the USPHC values for Dutch military personnel, also when they are deployed in desert countries. The guidelines were largely based on studies in situations with a high contribution of fossil fuel emission to the total particulates and there are indications that the effects of crustal particulates are less severe at similar exposure levels. Therefore, these guidelines are probably rather conservative for situations where exposure is largely to crustal particulates.

In the report on information on recovery of chemical exposure, a method was developed to derive borders for situations with no effects likely to occur (green), effects with complete recovery being highly likely (yellow), effects for which irreversibility cannot be excluded (orange) and a high risk of non-reversible effects (red) (18). For particulate matter, the information on reversibility of effects and on the dose effect curves is too limited to allow the full use of this method.
The MEGs set for particulate matter differentiate more between the number of people expected to have adverse effects (in relation to their prior health status) than between reversible and irreversible effects. However, it is possible to provide a somewhat similar, though modified system of colours for the particulate matter MEGs. In this case green is still used for 'no (relevant) effects', yellow for 'reversible effects' and orange for irreversible effects. However, to indicate the different proportions of personnel expected to have effects above a certain limit, several shades of these colours are used.

Green → Only a small minority of personnel is expected to have (in general) reversible effects, generally of a minor nature; the expected lack of severity of effects and small number of effected persons still allow a conclusion 'green'
Light yellow → A substantial proportion of personnel is expected to have (in general) reversible effects; the effects may be more severe
Yellow → Most, if not all, personnel are expected to experience (in general) reversible, but very notable effects
Light orange → a small percentage personnel may develop chronic effects

Orange → A larger percentage of personnel may develop chronic effects.

The concluded guidelines can be summarized as given in Table 5 (more detail is in Tables 4A and 4B).

Table 5. Summary of the guidelines for particulate matter

Limit	Value $PM_{2.5}$	Value PM_{10}	Colour (when exposure above these values)
Annual (long-term) MEG; Marginal hazard	65 $\mu g/m^3$	Not defined	Orange
Annual (long-term) MEG; Negligible hazard	15 $\mu g/m^3$	Not defined	Light orange
24 Hour (short-term) MEG; Critical hazard	500 $\mu g/m^3$	600 $\mu g/m^3$	Yellow
24 Hour (short-term) MEG; Marginal hazard	250 $\mu g/m^3$	420 $\mu g/m^3$	Light yellow
24 Hour (short-term) MEG; Negligible hazard	65 $\mu g/m^3$	250 $\mu g/m^3$	Green

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6. Signature

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