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Status Report on the Health Issues Associated with Pulverised Fuel Ash and Fly Dust

Introduction and Summary

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results

The report briefly sets out the environmental effects of a coal-fired power station and the health aspects of exposure to pulverised fuel ash, in particular. The average elemental composition of coal, bottom ash, and pulverised fuel ash, fly ash and fly dust are listed.

The health related form of exposure is inhalation. It has been established that pulverised fuel ash does not possess any specific toxic properties and can therefore be considered a “nuisance dust” which means that the threshold limited values (TLVs) for nuisance dust apply. Only in the case of quartz do the threshold limited values (TLVs) of quartz not apply, since quartz in pulverised fuel ash does not possess the toxic properties of pure quartz or of some other quartz containing substances. In case of co-firing, methodologies were developed in order to assess quickly whether the resulting pulverised fuel ash can still be interpreted as a nuisance dust (non toxic dust).

The exposure of **employees** to pulverised fuel ash is such that no TLVs are exceeded. This means that pursuant to all present health standards it can be concluded that the health of employees working in power stations or involved in shipping or processing pulverised fuel ash and that of their offspring will not be harmed. Only during incidents where for short periods of time dust concentrations may be above the TLVs, is protection necessary to limit exposure.

Pulverised fuel ashes originating during the co-firing of the examined secondary fuels differ very little from pulverised fuel ash originating during the firing of coal only. The conclusions apply exclusively to the co-firing of the examined secondary fuels in proportions of up to 10% by dry mass.

Coal dust is not carcinogenic. The, by Born derived, “No Effect Level” (NEL) for respirable coal dust of two milligrams per cubic metre, should give sufficient protection against health impairment. This means that the Dutch and German TLVs for respirable coal dust offer sufficient safety, regardless of the quartz content. Due to uncertainties as to the starting-point the results of an extensive epidemiological study in the US is not taken into consideration. Based on this study NIOSH has proposed a standard of one milligrams per cubic metre. It is also important to bear in mind that a lot of the research conducted has been concerned with coal-mine dust. Coal-mine dust is a mixture of coal dust and rock, and the rocks in question contain a lot of quartz.

The exposure of **people living in the vicinity** of coal-fired power stations to flue gas components such as fly dust is negligible. The exposure of people living near pulverised fuel ash depots to airborne pulverised fuel ash is such that at the edge of the premises the background concentrations of fine dust (PM_{10}) will increase on yearly basis by 6,5 percent, which can still be considered negligible. Deposition five hundred metres from the centre of the source is between 0,4 and 1,9 grams per square metre per month, i.e. around the subjective nuisance threshold.

3 OCCUPATIONAL HEALTH AND SAFETY ASPECTS OF PULVERISED FUEL ASH

3.1 Introduction

Topic report number 1 deals with health and safety implications of working with pulverised fuel ash as a dust.

KEMA-DAM® (KEMA Dust Assessment Methodology) is a tool with which it is possible to easily determine whether the Threshold Limited Values (TLVs) set by the Dutch health authorities for macro-elements and trace elements in ash are likely to be exceeded in the event of exposure to pulverised fuel ash dust. KEMA-DAM® is used as a means of risk assessment.

3.2 Results

The most important route for exposure to pulverised fuel ash is inhalation. People involved in the production and processing of pulverised fuel ash can be exposed via this route. Measurements indicate that, under normal operating conditions, concentrations of inhalable pulverised fuel ash associated with occupational exposure in power stations vary between 0,1 and 7 milligrams per cubic metre, while concentrations of respirable pulverised fuel ash associated with such exposure are between 0,1 and 2,3 milligrams per cubic metre. During maintenance or in the event of an accident, certain individuals may be exposed to higher concentrations. Under such circumstances, breathing equipment will be worn.

A great deal of research has been conducted into the health implications of working with pulverised fuel ash. Data from cell test systems and animal experiments indicates that normal levels of exposure (i.e. exposure to levels below the limit for nuisance inhalable substances) are not likely to have any significant health implications. The results of epidemiological research confirm this conclusion.

3.3 Conclusions

- The applied research and this risk estimation indicate that there is no reason to regard pulverised fuel ash as a “harmful” dust as opposed to a “nuisance” dust. No increased health risk is involved as long as the requirements laid down for nuisance dust in the occupational environment are met. This means that the standards for nuisance dust should be applied.

which airborne pulverised fuel ash settled would thereby be polluted, while a specially developed KEMA model was used to assess the risk of small children suffering adverse effects as a result of swallowing pulverised fuel ash.

4.2 Results

The particle size distribution in pulverised fuel ash was determined on the basis of the internationally accepted differentiation between an inhalable fraction (consisting of larger particles), a fine fraction and a respirable fraction. In order to assess the implications for high-risk groups, such as small children and CNSLD sufferers, an additional very fine fraction was also defined.

Ten per cent of the mass of pulverised fuel ash is accounted for by particles of less than 4,5 micrometres in diameter (± 0,2 micrometres). Fifty per cent of the mass consists of particles of less than 21,4 micrometres (± 3,2 micrometres). Particles of less than 90,4 micrometres (± 10,8 micrometres) make up 90 per cent of the mass. The diameters are expressed as their geometric or projected diameters.

The proportions of the mass accounted for by inhalable particulate material (PM_{50}), fine particulate material (PM_{10}), respirable particulate material (PM_4) and very fine particulate material ($PM_{2.5}$) average 55 per cent, 20 per cent, 5 per cent and 1 per cent, respectively.

Models of the airborne dispersal of pulverised fuel ash at and near a storage site indicate that, in the area where people work, concentrations of the inhalable suspended pulverised fuel ash average 0,07 milligrams per cubic metre. Concentrations of the respirable fraction average 0,006 milligrams per cubic metre. Over the course of a year, the highest hourly average concentrations of the inhalable fraction in that area are between 0,8 and 7,5 milligrams per cubic metre, depending on the precise location, while concentrations of the respirable fraction are between 0,1 and 0,9 milligrams per cubic metre. The TLV for inhalable particulate material is 10 milligrams per cubic metre and the corresponding figure for respirable particulate material is 5 milligrams per cubic metre. These TLVs are eight-hour average figures; transient concentrations up to twice as high are permitted. The model calculations indicated that neither TLV was exceeded in any hour or at any location.

Around the perimeter of the power station site, where members of the public may be exposed, the annual average concentrations of fine particulate pulverised fuel ash are up to 2,6 micrograms per cubic metre. The highest hourly average concentration in the course of a year are at the northern perimeter, where meteorological conditions may result in 31 micrograms per cubic metre being reached. This would increase the annual average background concentration of fine particulate material by up to 6,5 per cent. This is within the range of natural variations in background concentrations and therefore negligible.

Deposition five hundred metres from the centre of the source is between 0,4 and 1,9 grams per square metre per month, i.e. around the subjective nuisance threshold. The HESP model was used to calculate what the consequences of prolonged deposition (i.e. deposition over a period of a hundred years) of pulverised fuel ash on the soil would be for human health. For the purpose of the calculations, it was assumed that meat, milk, eggs and vegetables from the deposition area would be consumed. The calculations indicated that the acceptable daily intake (ADI) values for the various elements found in pulverised fuel ash would not be exceeded. Small children form a special group in relation to exposure via deposition, because of their inclination to put anything they find in their mouths. On the basis of pessimistic assumptions, it was calculated that a small child could swallow as much as 0,1 grams of pulverised fuel ash. Given the composition of pulverised fuel ash, the insolubility of the ash particles and the leachable nature of the elements concerned, it is believed that effective intake by the body would be too small for adverse effects to result.

In the Netherlands no buildings are located less than five hundred metres from a power station. In the event of a worst-case accident, involving the release of one tonne of pulverised fuel ash per hour (278 grams per second), the particulate material concentrations five hundred metres from the plant would be quite high: 17 milligrams per cubic metre for all particulate material (TSPM) and 3,5 milligrams per cubic metre for fine particulate material. Deposition would be 2,6 grams per square metre per month.

4.3 Conclusions regarding implications for power plant personnel

- The concentrations of airborne pulverised fuel ash to which personnel working in storage areas are normally exposed are below the Threshold Limited Values (TLVs) established by the Dutch Health Authorities for respirable and inhalable nuisance dust.
- In the event of a worst-case accident, personnel working on the power plant site would be exposed to high concentrations of airborne pulverised fuel ash. Within seven hundred metres of the accident site, these concentrations would exceed the TLV for inhalable nuisance dust. Exposure to respirable particulate material (which is more important in relation to health) would, however, remain below the TLV, because the duration of exposure would be brief.

4.4 Conclusions regarding implications for the general public

- People living in the vicinity of a coal-fired power station with an open pulverised fuel ash storage facility may be exposed to airborne pulverised fuel ash. In absolute terms, the concentrations involved are low and negligible in relation to normal background levels. Hence, the airborne dispersal of pulverised fuel ash does not lead to the recommended limits for fine particulate material being exceeded. The amount of pulverised fuel ash deposited near the perimeter of the site could be perceived as a nuisance, but is not sufficient to constitute a health hazard.

- Only in the event of an accident could the relevant limits be exceeded locally. Following an accident, the concentration of fine particulate material in the atmosphere could exceed the recommended limit at distances up to one kilometre from the source. However, given the composition of pulverised fuel ash, damage to health is not likely to result. Nevertheless, CNSLD-sufferers could suffer irritation, shortness of breath. The level of deposition resulting from an accidental release lasting one hour would be roughly equivalent to a month's deposition under normal circumstances. This would be sufficient to be perceived as a nuisance up to one kilometre from the source, but will not lead to damage the health.

8 THE ROLE OF QUARTZ IN COAL AND IN PULVERISED FUEL ASH AND HUMAN EXPOSURE

8.1 Description

Topic report number 6 deals with quartz. Exposure to quartz can lead to “black lung” or more precisely pneumoconiosis or silicosis. Especially the malignant condition progressive massive fibrosis (PMF) is serious. For PMF to occur a number of limiting conditions need to be met. The particulate material containing the quartz must be respirable (i.e. sufficiently fine that it is able to penetrate deep into the lungs). The surface of the material is also very important, since it is believed that surface radicals act as the trigger. Surface radicals are found mainly on freshly created surfaces and their formation can be inhibited by weathering/ageing and by the presence of other substances, such as aluminium and some forms of iron. As well as causing silicosis, it is recently known that quartz is a human carcinogen at concentrations above a certain threshold.

Since quartz is found in coal and pulverised fuel ash, it is important to know the concentrations in which it is present and whether its presence can cause fibrosis or cancer.

8.2 Results: quartz in coal

Coal fired in the Dutch power stations contains quartz in concentrations of between 0,5 and 7 per cent. The weighted average concentration is roughly 2 per cent. More important in this regard, however, is the quartz concentration in the respirable fraction of the coal. One sample was therefore analysed carefully. The absolute respirable quartz concentration was 0,02 per cent. Under the assumption that this sample is representative, it could mean that the quartz content of respirable coal dust is insignificantly low. More measurements must confirm this percept.

It is now believed that the significance of quartz in coal was overestimated in the past. Various other parameters, such as the leaching of iron, the presence of surface radicals and surface age are now thought to play a major role. Furthermore, the IARC does not class coal as a carcinogen. The conclusion is that at concentrations below the no-effect level (NEL) calculated for coal dust on the basis of epidemiological research, 2 milligrams per cubic metre, exposure will not have adverse health consequences. The NEL was based mainly on research among miners exposed to colliery dust with various (high) quartz concentrations. Colliery dust differs from coal dust in that it contains not only coal particles, but also particles of rock, including sandstone, which have much higher quartz concentrations. Furthermore, in collieries, fresh surfaces are constantly being formed. By contrast, coal fired at Dutch power stations is imported by sea and its surfaces have weathered for some while. Consequently, application of the NEL as a concentration limit in Dutch power stations, effectively provides an additional safety limit. In the Netherlands, the Threshold Limited Value (TLV) for respirable coal dust is 2 milligrams per cubic metre. This figure allows for the presence of quartz in the dust. In view of the considerations set out above, no further limits need to be applied to ensure that quartz does not present a health hazard to power station personnel.

8.3 Results: quartz in pulverised fuel ash

In Dutch power stations, when coal is fired, approximately 50 per cent of the quartz is vitrified. This vitreous material is one of the main components of pulverised fuel ash. The remainder of the quartz finds its way into the pulverised fuel ash in non-vitreous form. Most of this quartz is found in the non-respirable fraction of the ash; the respirable fraction contains only about 1 per cent of the quartz. In absolute terms, quartz accounted for roughly 0,1 per cent of the respirable fraction of the pulverised fuel ash samples tested. Between 60 and 86 per cent of this quartz was embedded in the ash particles and therefore not available at the surface. Thus, only a very small amount of the quartz is biologically available.

In the work area directly underneath the E-filter, the measured stationary respirable atmospheric quartz concentrations under normal stationary conditions average 0,0005 milligrams per cubic metre. That is less than 1 per cent of the TLV for quartz, which is 0,075 milligrams per cubic metre.

All the research undertaken, including epidemiological, *in vivo* and *in vitro* studies, indicates that quartz in pulverised fuel ash does not have the same effect on humans or animals as pure quartz or some quartz containing substances and does not constitute a fibrogenic risk. However, exposure to respirable pulverised fuel ash in concentrations of more than 5 milligrams per cubic metre can result in functional impairment of the lungs and respiratory complaints. At even higher concentrations, there is a risk of chronic bronchitis. However, these effects are what one would expect from any particulate material (nuisance dust); they are not specific to pulverised fuel ash and are certainly not attributable directly to the presence of quartz in the ash.

The absence of the effects normally associated with quartz is attributable to the fact that the quartz in pulverised fuel ash is mainly enclosed within vitreous material. This has been established by electron microscopy of roughly eleven thousand cross-cutted pulverised fuel ash particles. Moreover, it appears that quartz loses its fibrogenic properties when heated to temperatures of more than 1200 °C. All pulverised fuel ash particles undergo heating in excess of this level.

The Dutch Health Council's Expert Committee on Occupational Standards assumes that inhaled quartz particles can cause lung fibrosis, leading to the development of tumours, as a result of prolonged irritation of the lung tissue. Since pulverised fuel ash does not have any of the effects normally associated with quartz, it is highly unlikely that the quartz in pulverised fuel ash is carcinogenic.

8.4 **Conclusions**

- The effects of quartz on human health depend on a range of parameters. The effects of quartz in coal are reduced by the coal itself. Exposure to coal dust in concentrations below the relevant TLV should not have any adverse consequences for human health.

- Pulverised fuel ash of the kind produced at power stations firing pulverised coal in the Netherlands does not have any of the effects (e.g. silicosis) normally associated with quartz. Hence, the TLVs for quartz are not appropriate for the quartz found in pulverised fuel ash.