DIFFUSE PM10 EMISSION MEASUREMENTS SOME CASE STUDIES

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Abstract: In Europe only a draft guideline exists for the measurement of diffuse emissions of PM10 particles. No European standards are implemented. In this article four different cases in which PM10 emissions were established, are described. In the first case PM10 emission potentials of materials were determined using a vertical flow dust chamber. In the second case the measurement of diffuse emissions due to the ventilation of a half-open production site is described. In the third case the PM10 emission of a stone crusher was measured by means of up and downwind measurements of PM10 concentrations. In the last case fluctuating dust emissions occur due to wind erosion of stockpiles and handling activities. The dust emissions were established by continuous monitoring the PM10 and coarse concentrations, followed by reverse dispersion model calculations.

1. Introduction

Due to European legislation much attention has been paid in the Netherlands to the PM10 emissions of industrial sources. In most cases PM10 emissions are calculated using emission factors found in literature, for instance from US EPA (2004), or from Mulder, 1986. In some cases however emission factors are not available, or are too old to be used in the current situation. Major sources of fugitive PM10 emissions are:

- The transport, handling and storage of materials in the open air, for instance sand, ores, minerals and coal.
- Windblown emissions from storage piles.
- The transport of materials by means of conveyer belts and elevators
- Windblown dust emissions from the soil, roads and vehicles.
- The processing of minerals and ores in the open air.

Depending on the mechanisms on which PM10 emissions occur, different measurement strategies have to be employed. The different manners, in which PM10 emissions can occur, are summarised in table 1.

From this table it shows that guidelines only exist for the performance of source emission measurements and work place PM10 concentration measurements. For the determination of fugitive PM10 sources, only a draft guideline exists (CEN, 2004).

This paper describes PM10 emission measurements of fugitive sources in four different emission situations varying from simple to complex.

Table 1. Overview of measurement strategies and principles to determine PM10 emissions from different sources

PM10 source	Measurement strategy	Principle	Guidelines	Examples
Stack emissions	Source emission measurement of PM10	Sampling PM10 dust in fluegasses by means of a Cascade Impactor	VDI 2066-5:1994	Mills Industrial Sources
Room ventilation	Indoor air PM10 concentration measurement combined with the determination of the room ventilation rate	Sampling PM10 dust in indoor air by means of a cyclone	MDHS 14/3: 2000 NEN 1087:2001	Welding activities Mineral Industry
Handling pulverulent? materials	Measurement of PM10 emissions during handling using a vertical flow dust chamber	PM10 concentrations in the dust emissions after handling with conveyer belt, are measured with a Cascade Impactor	None	Harbour activities
Storage piles	Measurement of wind erosion of PM10 dust in a wind tunnel	PM10 concentrations in the windtunnel are measured with a Cascade Impactor, using different wind speeds	None	Storage piles
Dust sources in open air	Measurement of windward and leeward PM10 Concentrations and wind speed	Mass balance method	None	Stone crusher Conveyer belts
Complex industrial sources	Continuous PM10 concentration monitoring	Mass balance method Reverse dispersion model calculations	None	Mineral Industry

2. General principles of down wind and up wind methods

The PM10 emissions of fugitive sources are diffuse emissions and the emission rate depends on a number of factors, such as:

- Characteristics of the particles such as the composition, the specific gravity, the particle size distributions.
- Meteorological parameters e.g. rainfall and wind speed.
- Use of reduction measures such as filters, covering of piles, windshields and the use of water or adhesives.
- The use of best practices to control dust emissions. For instance, minimising dropping height during handling, minimising the height of the stockpiles, cleaning the surfaces and spreading water and minimising the driving speed of trucks.
- The process activities in the open air.

The PM10 emission of dust sources in the open air is determined by means of windward and leeward measurements. The PM10 concentration and the wind speed are measured up-and downwind of a source. From these measurements, the PM10 emission of the source is calculated with the following expression:

$$E = A*U*(C_{downwind} - C_{upwind}) \quad [1]$$

Where:

E PM10 emission [kg*s^{-1}]
A Total vertical surface of the measurement plane [m^2]
U Wind speed [m*s^{-1}]
C The measured downwind and upwind PM10 concentration

The main sources of error of this method are the determination of the measurement plane and the representative sampling of the PM10 concentration in the plane. The dimensions of the measurement plane are determined by the source dimensions and the dimensions of the plume (for instance calculated with a Gaussian plume model). It is preferable to measure the average PM10 concentration in the sample plane, by means of a mobile measurement. Due to the dimensions of the measurement equipment, this will be difficult to do in most cases. In cases in which the PM10 concentration in the plane is expected to be uniform, measurements at one spot may be sufficient. If concentrations vary significantly however, measurements should be performed at more then one position, the number depending on concentration variations and the elongation of the measurement plane.
When these emissions not only depend on process conditions, but also on windspeed, the measurements have te be performed at different windspeeds.

The PM10 emissions of fugitive sources will vary constantly in time. These emission variations can be determined by monitoring the PM10 concentrations at different locations around the source during a representive period. In a typical PM10 concentration monitoring program, the concentrations are measured at 3 positions during a period of 4 to 6 weeks. During this period windspeed, wind-direction and rainfall are monitored at site. For each hour the PM10 emission can be calculated using expression [2].

$$E = DF * (C_{downwind} - C_{upwind}) \qquad [2]$$

Where:

DF Disperion factor [$m^3 * s^{-1}$]

Depending on the wind-direction one measurement position is located upwind, and the others are located downwind. The dispersion factor is calculated with a dispersion model. For PM10 measurements a Gaussian Plume Model can be used. With these data, the relation between PM emissions and windspeed and rainfall can be detemined statistical. In the case of more then one dust emission source, multiple regression can be used to determine the emissions of individuel sources.

3. Measurement methods

The equipment for measuring dust concentrations in the outdoor air can be divided in to:
- PM10 or PM2.5 measurement equipment.
- Equipment for measuring coarse dust concentrations.
- Total dust concentration measurement devices.

The equipment used by Buro Blauw is summarised in table 2.

Table 2. Overview of dust concentration measurement equipment for the outdoor air

Dust fraction	Supplier	Measurement principle	Averaging time	Validation / Guidelines
PM10 /PM2.5	R & P	TEOM	Continuous	CEN (2001)
PM10	Leckel	Low volume sampler Gravimetry	1- 24 hours	NEN-EN 12341 Reference method
Coarse dust	Buro Blauw	Coarse dust recorder Automatic image analysis	1 hour	Novem (1991)
Total dust		Aerosol windtunnel sampler Gravimetry	1 - 24 hours	Novem (1991)

In Europe the measurement of PM10 in the outdoor air is standardised (EN 12341). According to this method outdoor air is sampled with a PM10 sampling probe, directly coupled with a filter substrate and a regulated flow device. The sampling is followed by gravimetric determination of the PM10 mass collected on the filter. The method is labour intensive and is not suitable to determine hourly averaged concentrations over a period of several weeks. In these situations an ambient PM10 monitor (TEOM principle) is used. This monitor measures dust concentrations by means of the tapered element oscillating microbalance principle. Outdoor air is sampled continuously with a PM10 (or PM2.5) sampling inlet.

The inertial balance measures directly the mass collected on an exchangeable filter cartridge by monitoring the corresponding frequency changes of a tapered element. The sample flow passes through the filter, where particulate matter is collected, and then continues through the hollow tapered element on its way to an active volumetric flow control system and vacuum pump. To compare the results of the TEOM with the reference method (IEN-12341), weekly PM10 concentrations are measured simultaneously at the same position with a low volume sampler.

The measurement of the coarse dust concentration is not yet standardised. Buro Blauw developed the Coarse Dust Recorder. The CDR consists of a tube mounted on a tripod. In the tube a constant air velocity is maintained with a fan. The recorder is always kept aligned with the wind direction by means of a vane. The coarse dust is collected on a strip coated with an adhesive. Each part of the strip is exposed to outdoor air during 20 minutes. The dimensions of the coarse dust recorder are chosen in such a way that the 50% cut-off aerodynamic diameter of the sampled particles is 14 µm. The sampled dust on the strip is analysed in the laboratory with an automatic image analysis system. The area covered by particles is determined as well as the particle size distribution. The effective area coverage is converted into the coarse dust concentration by means of an experimentally assessed conversion factor.

The total dust concentration is measured with an aerosol windtunnel. This tunnel is also mounted on a tripod with a fan and a vane. Total dust is collected by means of isokinetic sampling of the outdoor air in the tunnel over a filter. With the aerosol windtunnel hourly averaged or daily averaged total dust concentrations can be obtained by means of gravimetry.

4. Case studies

4.1. Determination of PM10 emission potentials

In order to establish PM emission factors, two test methods in the laboratory can be applied:

1. The vertical flowdust chamber for the determination of the emission factors for PM10 emissions during handling of materials.
2. The wind erosion tunnel for the determination of the emission factors for PM10 emissions due to wind erosion of piles.

In this case study, examples of two laboratory tests are shown.

The vertical flowdust chamber

The Vertical Flow Dust Chamber (Lundgren, 1988) is developed to determine the emission factor for the total dust emissions during the handling of materials such as coal, sand or ores. Figure 1 gives a scheme of the test equipment. The equipment consists of a cistern that is divided in two parts by means of a vertical plate. In one of two compartments bulk goods can be dumped with a constant speed with a conveyer belt. On the other compartment a dust filter is fitted. The dust containing air is sampled trough this filter. The amount of dust collected on the filter is weighted. The dust emission factor for handling is expressed in $g*kg^{-1}$ dumped materials.

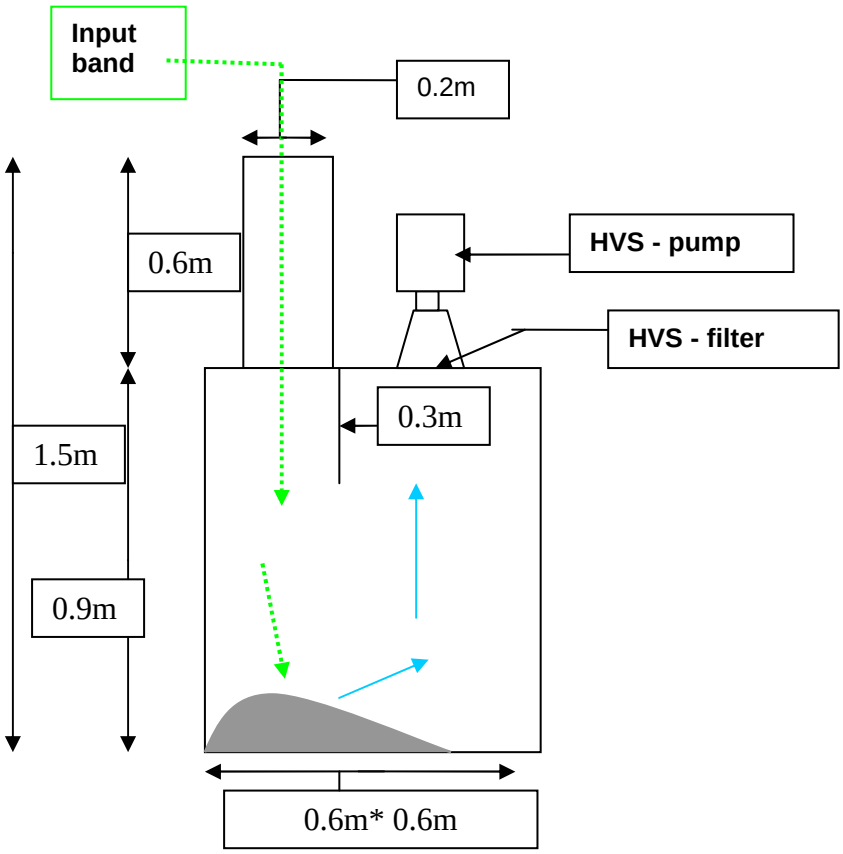

Figure 1. Scheme of a Vertical Flow Dust Chamber

Table 3 shows an example of test results typically for the VFDC.

Table 3. Emission factors for total dust and PM10 for different materials determined with the VFDC

Material	Total dust	PM10 dust	PM10 fraction in dust	Reproducibility
Between brackets the absolute moisture contents is given	Emission factor [g/kg]	Emission factor [mg/kg]	[%]	[%]
Fly ashes (0,9 %)	14	110	0,79%	30
Slag's (0,2 %)	3,8	9,1	0,24%	9
Chinees vloeispaat (0,9 %)	3,7	11	0,30%	10 – 22
Calcium fluoride				
Cement (0,3 %)	2,9	10	0,34%	5
Bentonite (6,7 %)	1,7	0,7	0,04%	10
Coal (0,9 %)	0,8	0,3	0,04%	60
Cat box material (0,2 %)	0,5	0,9	0,18%	8
Coarse sand (2,5 %)	0,4	1,2	0,30%	4
Barley (4,2 %)	0,3	0,1	0,03%	< 1
Silver sand (2,0 %)	0,1	0,2	0,20%	27
Silver sand (3,8 %)	<0,005	<0,002	0,04%	-
Crushed Stones	<0,005	0,01	0,20%	-
Rubble granules	< 0,005	0,007	0,14%	-

The wind erosion tunnel

The erosion wind tunnel is an instrument to determine emission factor of dust due to wind erosion. In figure 2 a scheme of the tunnel is given.

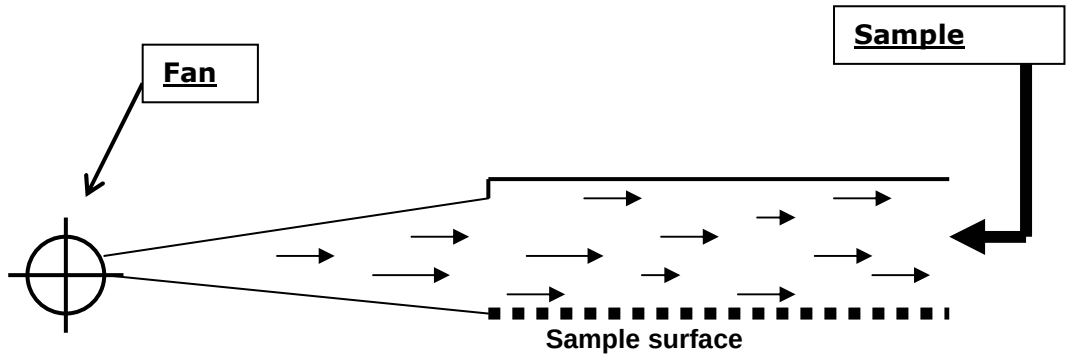

Figure 2. Scheme of the wind erosion test

The wind tunnel has an open bottom, which is placed over the material in investigation. Air is blown through the tunnel by means of an adjustable fan. Total dust is sampled isokinetically over a filter at the outlet of the tunnel. By using a cyclone, PM10 dust can be sampled. The erosion emission factor can be determined at different wind speeds and is expressed in $mg*m^{-2}*s^{-1}$. Table 4 shows some results obtained with the wind erosion tunnel. In this experiment fibre emission of fibre containing soils was measured at different wind speeds in the tunnel.

Table 4. Emission factors for wind erosion of fibres determined with a wind erosion tunnel

No.	Wind speed over the surface	Sampled air volume	Number of sampled fibres	Emission factor fibres	Coefficient of variation
	$[m*s^{-1}]$	$[m^3]$	[#]	$[\# *u^{-1}* m^2]$	[%]
1a	8,0	0,5026	< 1	< 1	
1b	8,0	0,4624	< 1	< 1	
Average	8,0		< 1	< 1	
2a	12,0	0,6367	3	38000	
2b	12,0	0,6941	1	12000	
Average	12,0			25000	74%
3a	14,0	0,5837	8	128000	
3b	14,0	0,586	13	207000	
Average	14,0			168000	33%

Discussion

In many cases it is not possible to perform dust emissions measurements at the source. The fugitive dust sources may not be attainable and there may be a cumulation of sources. Moreover emissions will vary in time due to variations in weather conditions and source activities.
In these cases emission factors can be determined under controlled conditions in the laboratory. The experiments presented in this paper show that reproducible results can be obtained with the VFDC (CV< 30%) and with the wind erosion tunnel (CV between 33%-74%). Due to the fact that the windtunnel experiment at a wind velocity of 12 $m*s^{-1}$ delivered a result close to the detection limit, a large coefficient of variation was found in this experiment. The results of the VFDC are suitable to investigate relative differences between the fugitiveness of bulk goods, or to examine the effectiveness of dust control measures, such as moistening or the use of adhesives. One should be cautious to use the absolute results in terms of emission factors. This is only allowed when test conditions such as dumping speed and height match the actual conditions. In combination with theoretical expressions, the test results may be a powerful tool to establish emission factors under different meteorological and process conditions.

4.2 Emission measurements at a half open production site

In this case ores are broken, filtered and packed in hall with one open site. The situation is presented in figure 3.

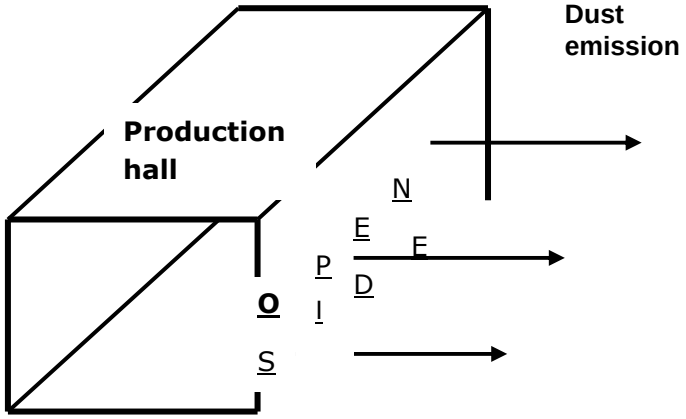

Figure 3. Schema of the PM10 emissions from a hall with one open site.

The machinery is places inside the hall and dust filters are installed on the machinery. The filtered air is recycled in the hall. PM10 emissions occur due to the natural ventilation through the open site of the hall. The dimensions of the open site of the hall are 125 * 6m. The total open area of the hall equals 750 m^2. The PM10 emissions of the hall are determined by measuring the PM10 concentrations and wind velocities at a number of virtual points in the ventilation plane. PM10 concentrations were measured using dust samplers fitted with a cyclone. Air velocities in the open site of the hall were measured using a heat anemometer. The results of the measurements are summarised in table 5.

Table 5. Results of the PM10 emission measurements at the half open production hall

Position	Activity in the hall	Height	Wind speed	PM10 Concentration
		[m]	[$m*s^{-1}$]	[$mg*m_o^3$]
1	Near exhaust filter package	4,40	0,45	0,52
2	Near exhaust filter package	2,50	0,33	0,64
3	Near crusher installation	4,30	0,56	0,85
4	Near crusher installation	2,65	0,31	0,33
5	Near filter installation	4,00	0,47	1,80
6	Near filter installation	1,50	0,26	1,40
	Average values		**0,40**	**0,92**
7	Background concentration	1,5	2,4	0,036

From the table it shows that measured PM10 concentrations vary between 0,33 and 1,80 $mg*m^{-3}$, depending on the position of the measurement. In this case the total PM10 emission of the hall equals, according to expression [1] equals:

$$E = A*U*(Cdownwind - Cupwind)$$ = 750*0,40*(0,92-0,036) = 264 $mg*s^{-1}$ or 0,95 $kg*h^{-1}$

In this case measurements were performed at only 6 places. It is likely that the PM10 concentration will vary depending on the place in the ventilation plane. The measurements were performed near the exhausts of the dust filters. Probably the measured PM10 emission is an overestimation. A more realistic result, with a less uncertainty would be obtained, if measurements were performed at more points in the ventilation plane.

4.3 Emission measurements of a stone crusher

Situation

A stone crusher is situated in the middle of an industrial site, at two sites surrounded by stockpiles of sand, rubble and crushed stones. Figure 4 shows the map of the measurement site.

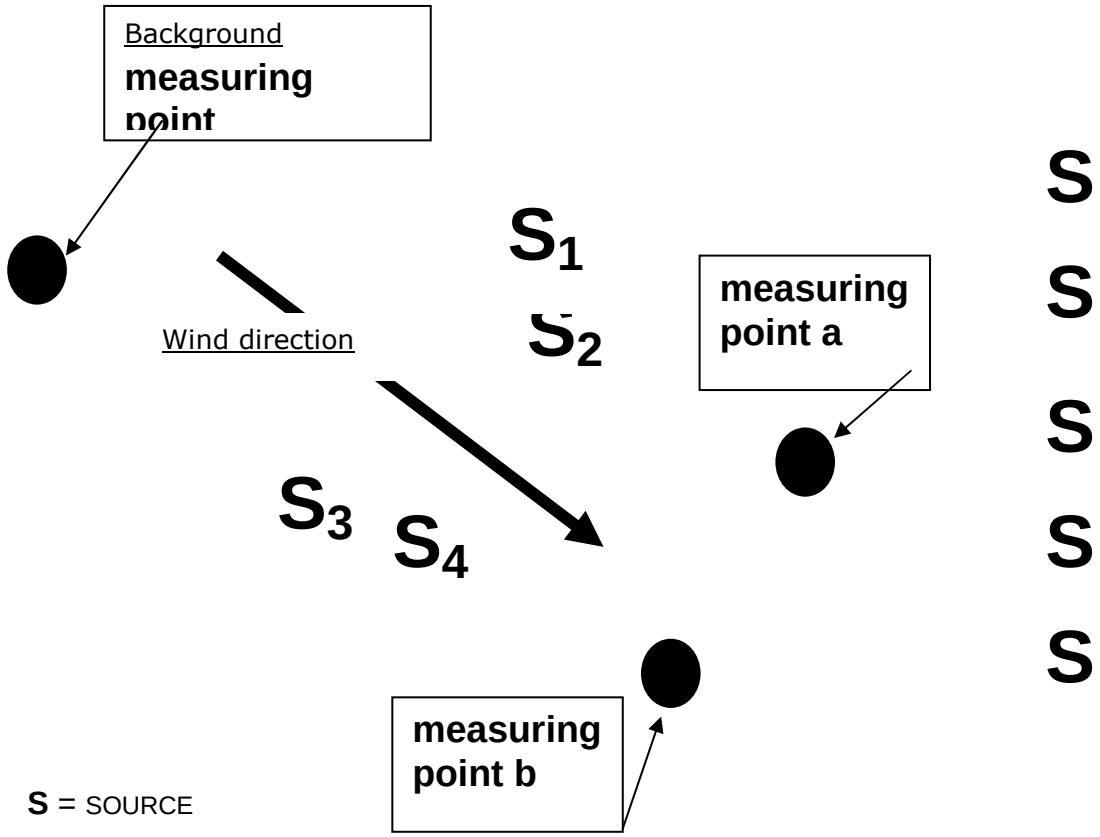

Figure 4. Map of the site of the stone crusher

The stockpiles (S) are situated in the North and the East site of the Stone crusher. Emissions occur during:

- unloading trucks with rubble (S1)
- dumping rubble on stockpiles (S3)
- crushing activities (S2)
- loading trucks with crushed rubble (S4)
- wind erosion of the stockpiles (S)

Measurement strategy

From figure 4 it shows that with wind coming from the South or the Northwest, up- and downwind PM10 concentration measurements can be performed, without disturbance of PM10 emissions of the stockpiles on the terrain. However the emissions due to unloading the trucks and due to the stone crusher could not distinguished from each other. ThePM10 concentration downwind of these sources was measured at point a in figure 4. Also the emissions of the dumping activities and loading of trucks could not be separated. The downwind concentration of these sources was measured at position b. Background concentration measurements were performed upwind, just outside the terrain

The PM10 concentrations were measured with low volume samplers according to EN 12341. At the same time the total dust emissions were measured with aerosol windtunnels. Finally wind speed and wind direction were monitored at a representative position in the vicinity of the source.

Results

The results of the measurements are summarised in table 6.

Table 6. Results of up- en downwind dust emission measurements of a stone crusher

Position	Source	Time	Concentration [μg*m^{-3}]		Source contribution		PM10 fraction
			Total dust	PM10	Total dust	PM10	[%]
-a-	Unloading and breaking	09:53-11:54	380	114	170	94	30%
	Background	10:09-12:20	210	20			10%
-b-	Dumping and loading	12:10-14:10	410	123	-	47	30%
	Background	12:25-14:25	480	76			16%

Form the table it shows that the total background concentration during the measurement of the PM10 emission from dumping and loading, exceeds the value of the down wind concentration of the source. In this case no total dust emission can be determined from the measurement. Probably the background concentration measurement was influenced by a very local source of coarse dust emissions.
The table also shows that the PM10 contents of the dust coming from both sources equals 30%, whereas the PM10 contents of the background dust equals 10-15%.
Furthermore it is concluded from this table that unloading and breaking activities contribute 170 μg/m^3 to the total dust concentration and 94 μg/m^3. Unloading and dumping add 48 μg/m^3 to the background PM10 concentration.
With this source contribution to the downwind dust concentrations and with the measured meteorological conditions during the experiments, the total dust and PM10 emissions of both sources are calculated, using expression [1]. The vertical surface of the measurement plane was calculated with a Gaussian plume model. The results of these calculations are shown in table 7.

Table 7. Determination of the total dust and PM10 emissions from up and downwind measurement at a stone crusher

	Unloading and Breaking	Dumping and loading
Vertical surface of the measurement plane [m^2]	434	476
Wind speed [m*s^{-1}]	2,1	2,4
Source contribution total dust [μg/m^3]	170	-
Source contribution PM10 [μg/m^3]	94	48
Total dust emission [g*h^{-1}]	**560**	**-**
PM10 dust emission [g*h^{-1}]	**308**	**197**

It is concluded that the total dust emission arising from unloading trucks and breaking rubble equals 560 g*h^{-1}. The PM10 emission of these sources equals 308 g*h^{-1}. From the activities dumping and loading only contribute to the downwind PM10 concentration could be determined. The PM10 emission of these sources equals 197 g*h^{-1}.

Discussion

This experiment shows that it is possible to perform dust emission measurement at diffuse outdoor sources. It also shows that in the measurement strategy local condition, such as the presence of other dust sources, should be taken in to account. In this example reliable measurements could only be performed at specific wind directions. Even then it was not possible to distinguish all sources and only accumulated emission of two groups of activities could be obtained from the measurements.
Because of these specific local conditions, emission monitoring during a representative period of 4 to 6 weeks wouldn't yield more representative results. In order to obtain reliable results it is recommended in this case to perform repetitive measurements under different meteorological conditions, such as wind speed and rainfall.

4.4 PM concentration monitoring of a fugitive mineral industry source

Situation

At the production site minerals are produced in ovens at high temperatures in the open air.
One production cycle lasts 14 days and consists of loading of the oven, the processing of minerals in the oven, the cooling of the oven and unloading the oven. In total there are 24 ovens. Not more than 7 ovens can be in activity simultaneously. The others are being loaded or unloaded or in maintenance. Figure 5 shows a scheme of the production site. During the production cycle dust emissions occur at:

- Blowing from unpaved parts of the terrain in the North-western part of the terrain. This source area is identified in this study as source area A.
- Stockpiles of raw materials in the northern part of the terrain, named source area B in this study.
- Dust emissions due to wind erosion of the ovens, during loading, cooling, and unloading, named as source area C, situated in middle of the terrain.
- Stockpiles of raw materials and end products, a stone crusher are situated in eastern part of the terrain and are identified with source area D.
- At the southern part (source area E) and North-eastern part (source area F) no dust emissions occur.

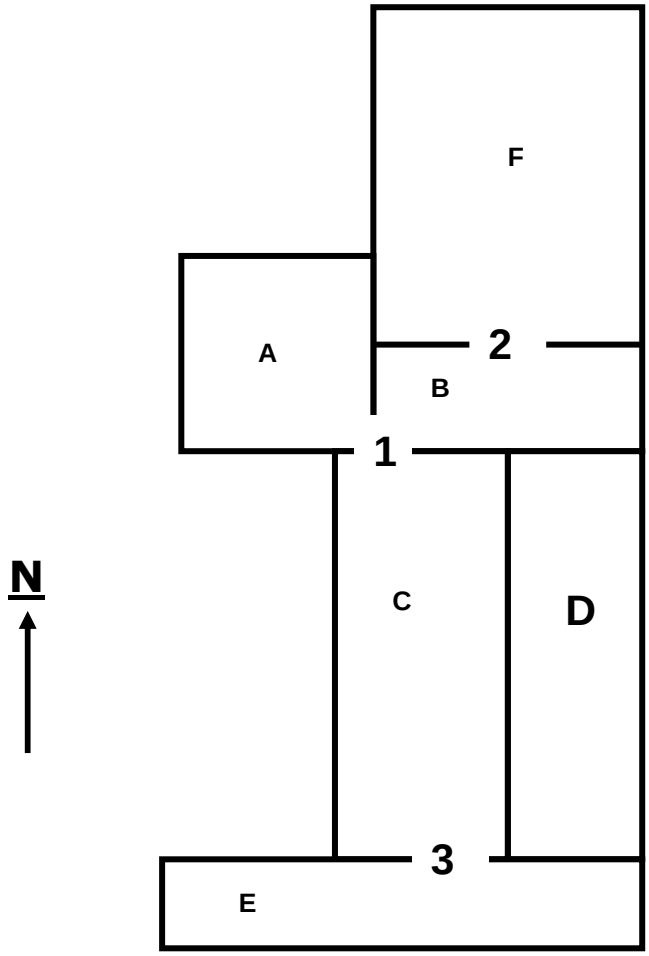

Figure 5. Scheme of the production site with source areas A – D and measurement positions 1 – 3

Strategy

Due to regulations in the environmental permit of the company, the total yearly dust and PM10 emissions had to measured. Depending on weather conditions (wind speed and rainfall), production activities and process conditions, the dust emissions of the different source areas vary in time. The yearly emissions were measured by means of a continuous dust concentration-monitoring program, during a representative period of 6 weeks.

Total dust and PM10 concentrations were measured at 3 points at the borders of the main source areas C en D of the terrain. Figure 5 also shows the position of the equipment (1 – 3).

At each position the coarse dust concentrations were monitored continuously with Coarse Dust Recorders. At these positions weekly averaged PM10 concentrations were measured with low volume samplers according tot NEN 12341. Additional PM10 concentrations were monitored continuously with a TEOM.

Emission estimates

The coarse dust emissions from the different sources were determined according to the draft European guideline CEN/TC 264/WG 17 N 145: " Fugitive and diffuse emissions of common concern to industry sectors- Fugitive Dust Emission Rate Estimates by Reverse Dispersion Modelling". For each hour of the measurement period coarse dust concentrations at the measurement positions 1 – 3, caused by the sources A – F, were calculated with EPA FDM model (Winges, 1990). In the calculations the dust emissions of each source were set at 1 $g*s^{-1}$. The total coarse dust concentrations were compared with the measured concentrations at the positions 1 - 3, using multiple regression analyses. Meteorological data from a nearby weather station were used in the model calculations.
To calculate the PM10 emissions of all sources first background concentrations at all wind directions were calculated. This background concentration was calculated from the TEOM data, at non-exposed wind directions. Also the data of the low volume samplers, at non-exposed wind directions, were used to calculate the background concentrations. From the TEOM data and the data of the CDR at position 2, the ratio between the coarse dust concentration and the PM10 concentrations for the sources A – D were calculated, taking the PM10 background concentration in to account.
Results

During the measurements the process activities were representative. In relation to long term average weather conditions, the wind speed during the measurement period was 25% higher. The results of the average coarse dust emission estimates are shown in table 8.

Table 8. Average coarse dust emission estimates of the sources A - F

Source Area	Particle size [µm] 20	50	70	Total
	Coarse dust emission [$g*s^{-1}$]			
A	0,11	0,15	0,11	0,37
B	0,09	0,13	0,20	0,42
C	0,42	0,65	0,64	1,70
D	0,52	0,78	0,98	2,28
E	<0,01	<0,01	<0,01	<0,03
F	0,05	0,04	0,02	0,11
Total	1,20	1,75	1,95	4,90

From these results it shows that coarse dust emissions occur from the area sources A (unpaved terrain), B (stockpiles of raw materials), C (ovens) and D (stockpiles of raw materials and end products and stone crusher). Depending on process and weather conditions, these emissions will vary in time. Table 9 shows the average coarse dust emissions with and without production activities.

Table 9. Coarse dust emissions in relation to process activities

Source Area	Coarse dust emission [$g*s^{-1}$] Daily average (see table 8)	With process activities	Without process activities	Ratio
A	0,37	0,7	0,2	3,5
B	0,42	1,0	0,1	10,0
C	1,70	3,5	0,9	3,5
D	2,28	4,9	1,4	3,5

It shows that coarse dust emissions during process activities are 3,5 – 10 times larger then emissions without process activities. The coarse dust emission estimates are clearly depending on process conditions. In source area B much transport and handling of raw materials takes place during daytime. This explains the high ratio of factor 10 of this source area compared to the ratio 3,5 of the other source areas. The relation between wind speed and coarse dust emissions are shown in figure 6.

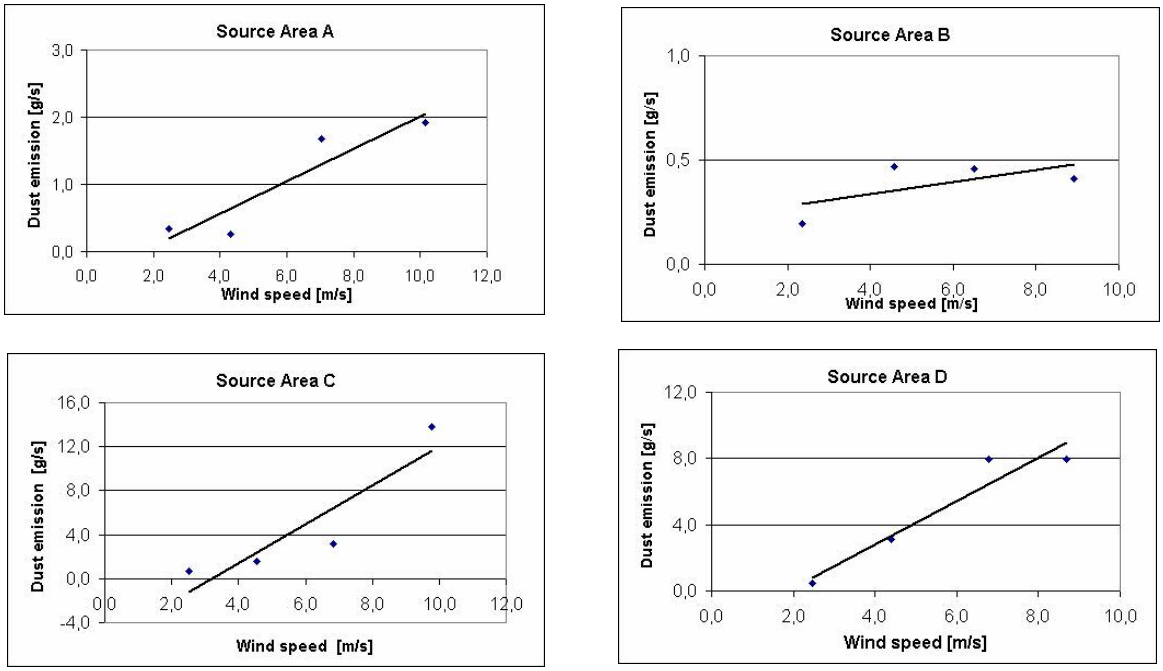

Figure 6 Relation between wind speed [m*s^{-1}] and coarse dust emission [g*s^{-1}] for the area sources A – D

From this figure it shows that dust emissions increase with increasing wind speed. This is what can be expected from a theoretical point of view. All relations were statistically significant ($P < 0,05$) and the coefficient of correlation for the source areas A, C en D was greater then 0,90, which is considered to be a good correlation. Only for source area B the correlation was weaker (0,63), for which no logical explanation was found.

No relation was found between rainfall and dust emissions. But rain fall and wind speed were correlated significantly ($P < 0,05$). Heavy rainfall occurred during periods with high wind speed, which may explain the lack of correlation between rainfall and dust emissions. In table 10 the yearly average coarse dust emissions are calculated using long-term wind speed statistics of the nearby weather station.

Table 10. Yearly average coarse dust emissions calculated from the long term wind speed distribution

Source Area	Coarse dust [g*s^{-1}] With activities	Without activities	[h*y^{-1}] With activities	Without activities	Correction Wind speed distribution	Total year Emission [t*y^{-1}]
A	0,7	0,2	4125	4635	59%	8,3
B	1,0	0,1	4125	4635	87%	13,5
C	3,5	0,9	4125	4635	36%	24,5
D	4,9	1,4	4125	4635	57%	55,0
Total	10,1	2,6				101,2

From the measurements with the low volume sampler at point 3 a background PM10 concentration was calculated of 24,3 µg*m^{-3} in week 5 and 29,3 µg*m^{-3} in week 6. From the TEOM data at point 2, an average PM10 background concentration during the measurement period of 26,9 ± 4,9 µg*m^{-3} was calculated. From this an overall background PM10 concentration was calculated of 26,8 µg*m^{-3}.

The ratios between coarse dust en PM10 concentrations for the different sources areas were calculated using the measured concentrations at position 2, and the measured averaged PM10 background concentration. Thereafter the PM10 emissions of the different area sources were calculated from these ratios. The results are given in table 11.

Table 11 Calculation of the PM10 emissions of the different source areas

Source area	Coarse dust emission [t*y^{-1}]	PM10-ratio	PM10 emission [t*y^{-1}]	Total dust emission [t*y^{-1}]
A	8,3	32%	2,7	11,0
B	13,5	37%	5,0	18,5
C	24,5	29%	7,1	31,6
D	55	49%	27,0	82,0
Totals	101,3	41%	41,7	143,0

This table shows average ratio between PM10 and coarse dust emissions of the source of 41%. The total dust emission of the source is 143 t*y^{-1}. According to the environmental permit a total dust emission of 163 t*y^{-1} is accepted. It is concluded that the measurements don't show a violation of the environmental permit.

Discussion

This example shows that with the draft European guideline for fugitive dust emission estimates reliable results are obtained for the coarse dust emissions. In this guideline the use of a dispersion model is crucial. The results are influenced strongly by the choice of the model. When the method of reverse dispersion modelling is being standardised, it is important to pay attention tot the criteria models should meet to be used in this method.
In this case PM10 emissions were established from calculated ratios between coarse dust and PM10 concentrations for different source areas. In principle it is preferable to determine the PM10 emissions in the same way as the coarse dust emissions were determined.

5. Conclusions

In most cases PM10 emissions of industrial sources in the Netherlands are calculated using emission factors. In the case of diffuse sources, emission factors may not be available or the literature data may be too old. Depending on the complexity of the situation PM10 emissions of diffuse sources, different measurement methods are available. Laboratory tests such as the Vertical Flow Dust Chamber and the wind erosion test can be used to obtain emission factors for dumping and wind erosion of fugitive sources. In cases in which diffuse emissions from different sources do not spatial intervene, emissions can determined with up- and downwind measurements. In order to obtain reliable results it is recommended to perform repetitive measurements under different meteorological conditions, such as wind speed and rainfall. In complex multiple source situations, in which emissions due to process conditions and meteorological conditions, vary in time, emissions of the different sources can be obtained by means of PM concentration monitoring during a representative period of time.
In all cases it shows that in the measurement strategy local condition, such as the presence of other dust sources, should be taken in to account. In order to obtain valid and reproducible results standardization of measurement methods is needed. When dispersion modelling is applied, it is important to pay attention tot the criteria models should meet to be used in standardised methods.

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