AN ON-LINE FUGITIVE DUST MONITORING NETWORK

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ABSTRACT

An on-line fugitive dust monitoring network was developed to monitor the fugitive dust emission of dry bulk terminals. Of the different size fractions measured, particles < 2.5 µm mostly originated from background sources, whereas particles measuring from 2.5 to 10 µm could be attributed to the source under investigation. The fugitive dust emission rate during a 24-day period was assessed by reverse-dispersion-modelling, using the measured dust concentrations and the weather conditions at the time of sampling. Software is being developed to monitor the current fugitive dust emission of the terminal and its impact on the surroundings.

INTRODUCTION

Fugitive dust emissions, from coal and iron ore storage and handling sites in the port of Rotterdam in the Netherlands, causes nuisance in residential areas due to dust deposition, and adds to the PM10 dust concentration. In order to reduce the dust emissions and minimise the environmental impact, DCMR Environmental Protection Agency Rijnmond and the dry bulk terminals EECV and EMO made an agreement to set up an on-line fugitive dust monitoring network.

PREVIOUS EVENTS

In 1996 and 1997, a study on the coarse dust emission of the storage and handling sites in the port of Rotterdam was carried out by the Technical University of Delft (Vrins *et al.*, 1998). For several months, coarse dust (particles > 10 µm) was sampled by Coarse Dust Recorders (Vrins, 1990). Over 10,000 hourly measurements of the coarse dust concentration (µg/m³) and particle size distribution were made at eight different receptor sites.

The emission rates were assessed by reverse-dispersion-modelling. Using the Fugitive Dust Model (FDM) (Winges, 1990), a dispersion factor was calculated. The dispersion factor **α** is the contribution of a local source **i** with emission rate **e** = 1 g/s to the concentration **c** at a

receptor site **r** downwind of the source. For coarse dust particles, the dispersion factor also depends of the aerodynamic particle size **d**.
In many cases, various sources contribute to the dust concentration at the measuring site. To distinguish between the contributions of these sources, a network of receptor sites is needed. Furthermore, using a time-series of measurements will increase accuracy.

$$c_{rd}(t) = \Sigma_i \; c_{ird}(t) = \Sigma_i \; \alpha_{ird}(t) \; e_{id} \tag{1}$$

The dust emission rates of the various sources were calculated by multiple regression (Vrins & Schulze, 1996), including that of the dry bulk terminals were assessed. Subsequently, the contribution of these companies to the dust deposition in the surrounding area was calculated.

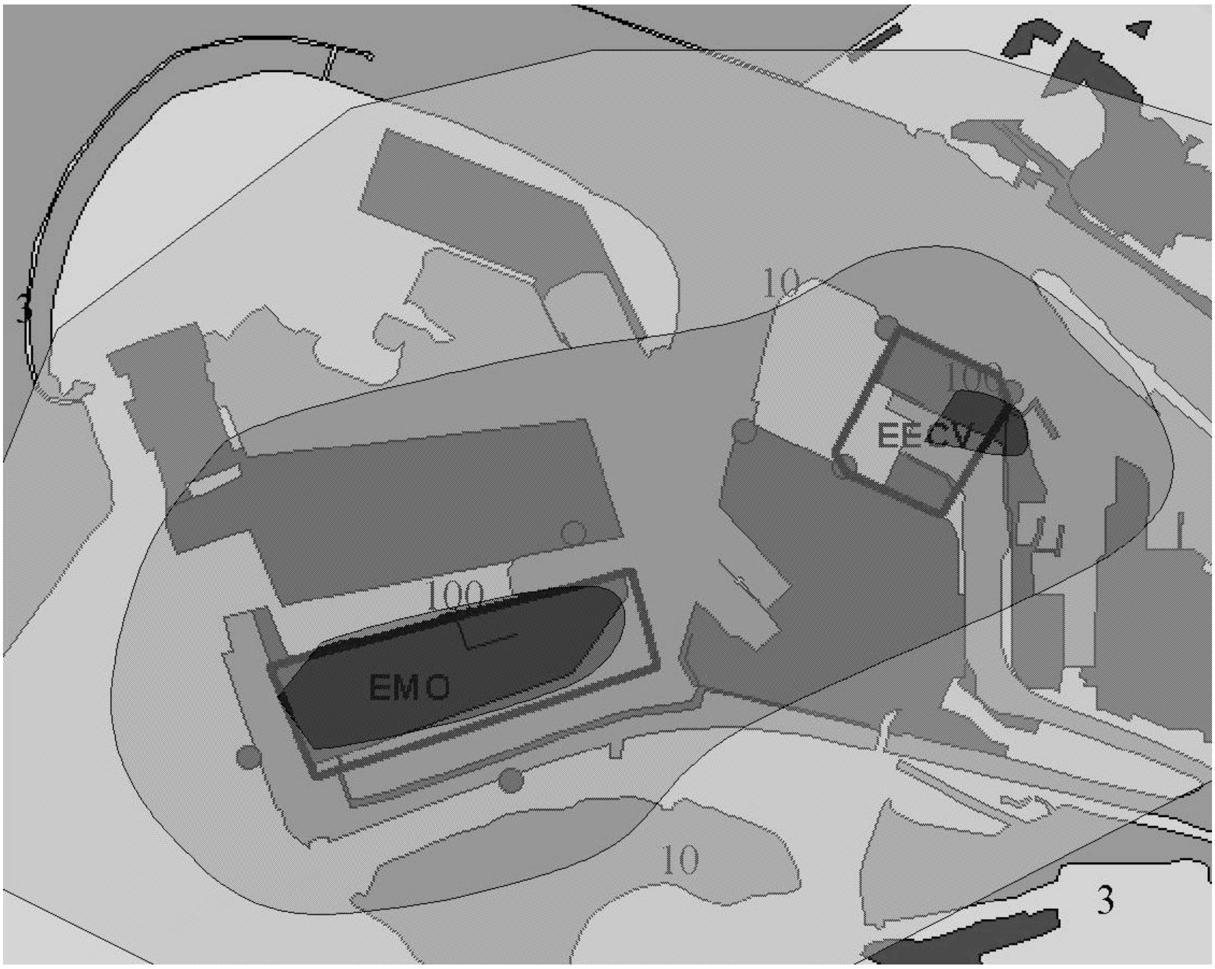

Figure 1. The yearly contribution of the dry bulk terminals to the dust deposition in the surrounding area in 1996 and 1997 (g/(m².year)).

More insight into the origin of the dust emissions was acquired by creating subsets on criteria, such as wind speed, handling activities and traffic intensity. This information helped in the choice of the most effective dust reduction measures.

This earlier study provided the appropriate information for a dust reduction policy. However, as the results are only available afterwards, these cannot be integrated into an on-line supervision system of the sort that makes it possible to intervene when dust emission rates increase to nuisance level. Therefore, on-line dust monitors should be used.

EXPERIMENTAL SET-UP

Choice of dust sampler

The most important requirements of an on-line dust monitor are: high sampling efficiency of coarse dust, a time resolution of at least one hour, particle size resolution and on-line availability of the dust concentration data. However, up till now, there is no on-line Coarse Dust Monitor available. There are only fine-dust-monitors to choose from. Although fugitive dust is mainly coarse, there will always be a fine fraction. This fine fraction is an indicator of the coarse fraction when their ratio stays the same. Distinguishing between fine dust sources is more complex than for coarse dust sources, as there are more fine dust sources present, such as traffic exhaust, the chemical industry, ships, and also the background concentration from sources too distant to identify. The difference between fugitive fine dust and that from these other sources is their size. Fugitive dust particles are predominantly larger than 2.5 µm, whereas the dust particles from these other sources are predominantly smaller than 2.5 µm. So, when there is a good correlation between coarse dust (particles > 10 µm) and the size fraction of 2.5 to 10 µm, a fine dust monitor might well provide sufficient information on the fugitive dust emission rate for the purpose of operational plant management.

The Osiris dust sampler fitted our purpose. The Osiris operates on the principal of light diffraction and has a virtually constant response, irrespective of the colour of the particles. This small sampler (0.2 m x 0.2 m x 0.5 m) gives a continuous and simultaneous indication of the PM1, PM2.5, PM10 and TSP mass fractions. Due to the low sampling rate (0.6 litres per minute), the sampling efficiency for large particles decreases. What is called TSP (Total Suspended Particulate) is actually about PM20 and, probably, the sampling efficiency depends on wind speed. Therefore, data analysis focuses on the size fractions PM2.5 and PM10.

Another reason why the Osiris sampler is chosen, is that it has low demands on the receptor site. It can be fastened to almost everything and only requires a low power supply.

Lay-out

To distinguish the contribution of a particular dust source from that from other sources, both the upwind and downwind concentrations must be measured. As wind direction is changing continuously, at least three samplers are needed around each dust source under investigation.

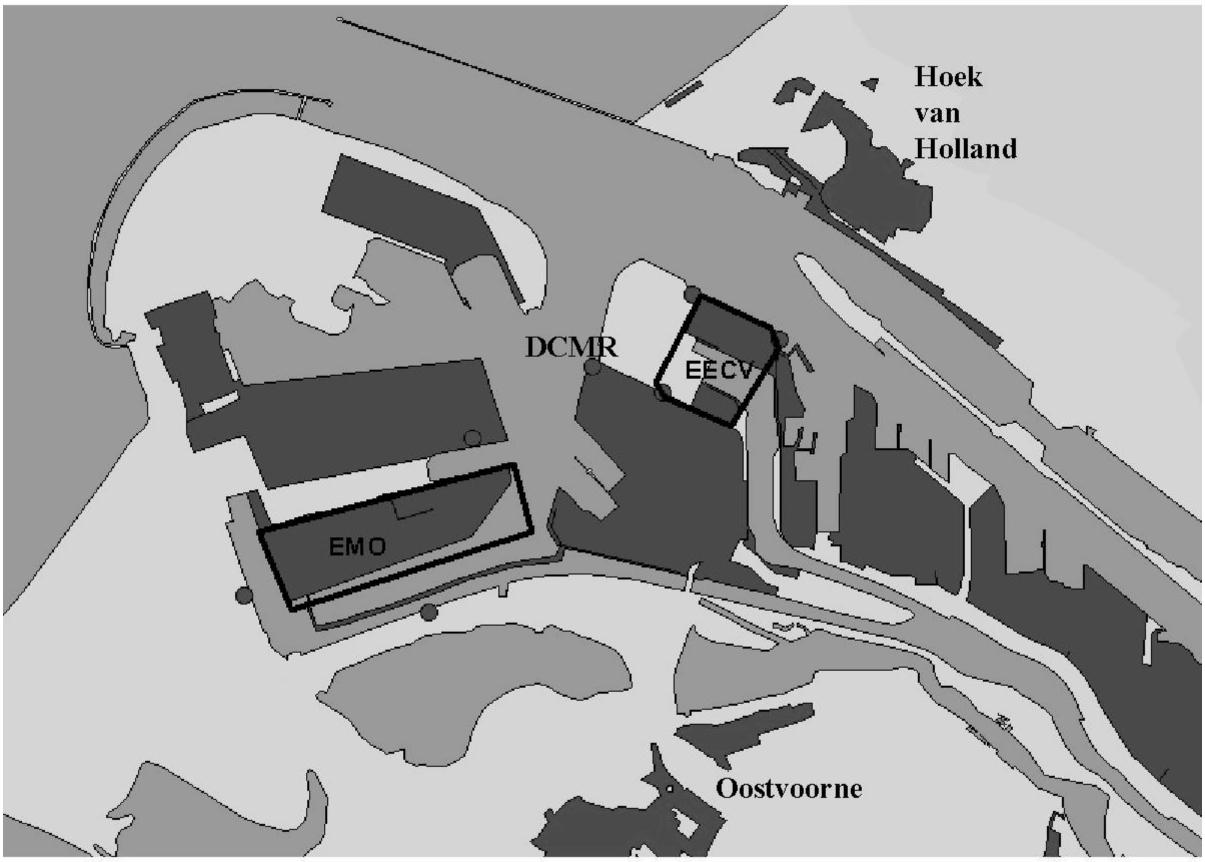

Figure 2. Receptor sites (dots) around the terminals EMO and EECV, the DCMR receptor site and the villages Hoek van Holland (NE) and Oostvoorne (SE).

Dust is measured every ten minutes by each sampler. Thus, at every terminal, eighteen dust measurements are available for an hourly estimate of the dust emission rate.

RESULTS

General

To illustrate the method, the results of a measuring campaign carried out for 24 days around the terminal of EMO are presented. Table 1 shows the general characteristics of the measurements.

Table 1 Hourly dust concentrations in µg/m³

	< 2.5 µm		2.5 – 10 µm		no. of observations
	mean	max	mean	max	
South of EMO	7	22	7	74	547
West of EMO	8	27	15	177	548
North of EMO	7	23	10	77	548

Background concentration and contribution of EMO terminal

The background concentration is defined as the contribution of local and more distant sources outside the industrial site under investigation. Mostly, the exact origin of this contribution is not known. The contribution of background sources is best shown by comparing the dust measurements at different receptor sites. When these dust concentrations are dominated by background sources, the concentrations are highly correlated, that is the correlation coefficient R^2 is close to 1. However, when the dust concentrations are caused by a dust source located in between the receptor sites, the correlation is very low.
Table 2 shows the correlation coefficients between the receptor sites for the size fraction < 2.5 µm (PM2.5).

Table 2 Correlation coefficients R^2 between receptor sites (size fraction < 2.5 µm)

	south of EMO	west of EMO	north of EMO
south of EMO	1	0.78	0.84
west of EMO	0.78	1	0.80
north of EMO	0.84	0.80	1

The correlation between the sites is quite high. This means that the measured PM2.5 mainly originates from background sources. This is illustrated by Figure 3 where the PM2.5 concentrations west of EMO are plotted against the PM2.5 concentrations north of EMO. As the simultaneous concentrations at both sites are almost equal, the contribution of the terminal in between is relatively low.

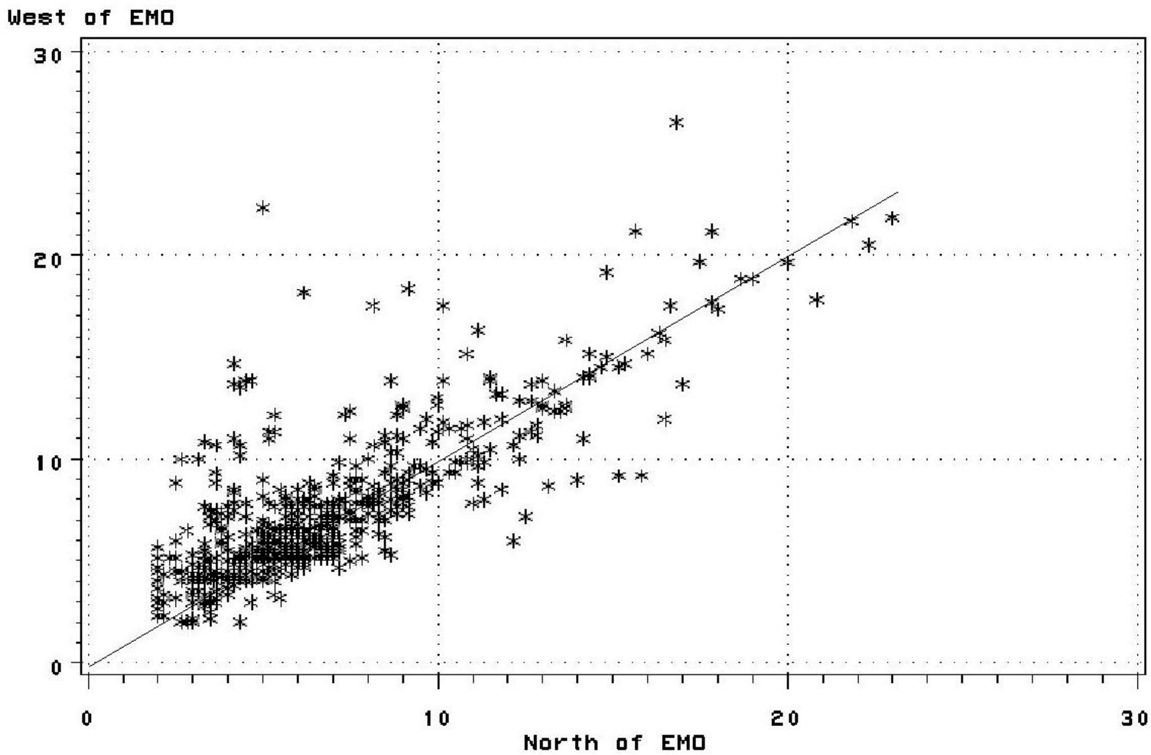

Figure 3 PM2.5 concentrations west of EMO plotted against PM2.5 concentrations north of EMO in µg/m³.

The correlation coefficients between the receptor sites for the size fraction 2.5 to 10 µm are much lower, ranging from 0.02 to 0.22 (Table 3).

Table 3 Correlation coefficients R^2 between receptor sites (size fraction 2.5-10 µm)

	south of EMO	west of EMO	north of EMO
south of EMO	1	0.15	0.22
west of EMO	0.15	1	0.02
north of EMO	0.22	0.02	1

Figure 4 shows the concentrations of this size fraction west of EMO plotted against the concentrations north of EMO. The large difference between the two sites shows that the terminal largely contributes to the concentrations measured.
The fact that the EMO terminal mainly contributes to the size fraction > 2.5 µm agrees with the expectation that the dust emission mainly consists of fugitive dust.

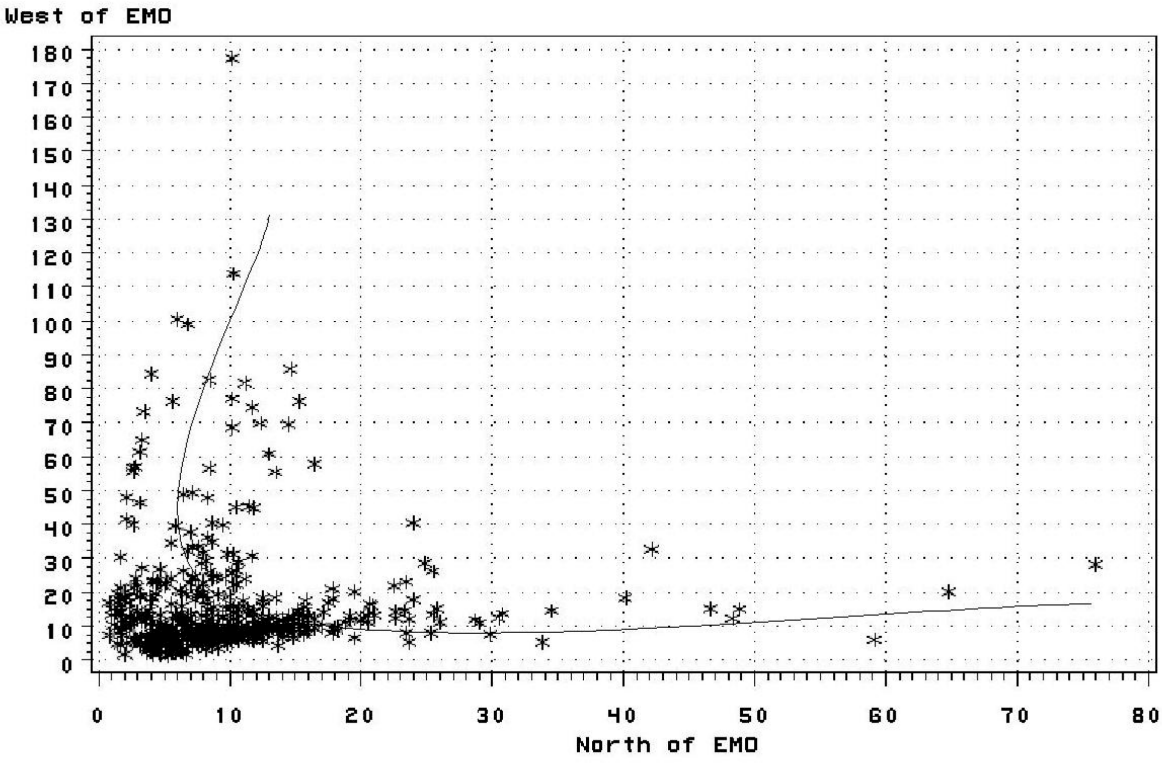

Figure 4 Concentrations of size fraction 2.5-10 µm west of EMO versus north of EMO in µg/m³.

Estimate of the mean dust emission rate

In 2003, the fine dust emission rate of the EMO terminal was estimated for every period of three months. Th emission rates ranged from 140 to 200 tonnes/year.

The mean dust emission rate (size fraction 2.5 to 10 µm) of the EMO terminal during this measuring campaign of 24 days was calculated by reverse-dispersion-modelling and amounted to 118 tonnes/year. This is in quite good agreement with the former estimates. The size distribution of the dust, emitted from the EMO terminal, was assessed in a former study (Vrins *et al*., 1998). As the coarse dust fraction (10 to 70 µm) was four times the fine dust fraction, the coarse dust emission rate is estimated at 472 tonnes/year.

On-line fugitive dust monitoring

Software is being developed to monitor the current fugitive dust emission of the terminal and its impact on the surrounding area. An example is shown in Figure 5.

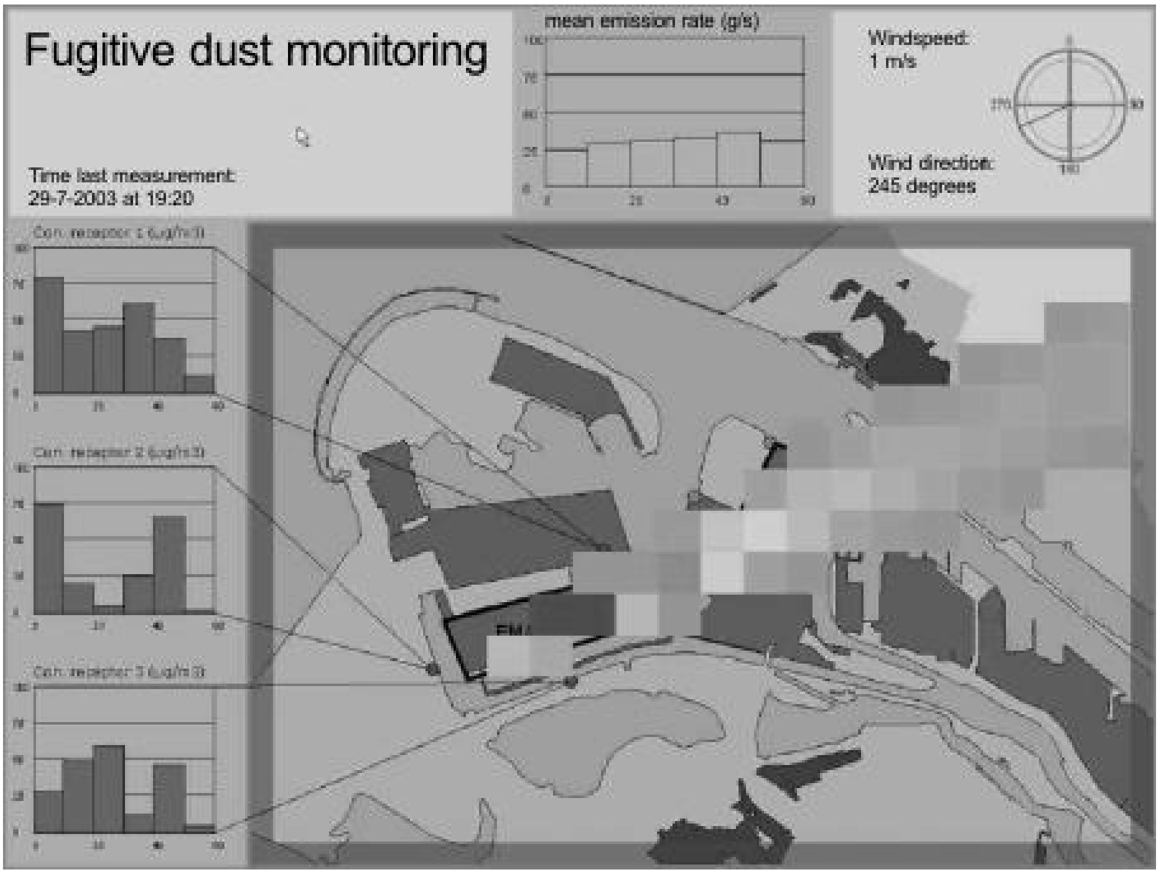

Figure 5. Current information for monitoring the fugitive dust emission. The plume shows the contributions > 1 µg/m³ of the EMO terminal to the fine dust concentrations.

On the left, the last six dust concentrations (size fraction 2.5-10 µm) at the three receptor sites. Top right, wind speed and wind direction, used for calculating dispersion factors. Top middle, the last six emission rates. In the main figure, the current dust plume. An alarm can be set to go off when a certain value is exceeded.

The on-line monitoring system is meant to provide the plant operators with the necessary information to intervene when dust emissions are rising and nuisance is likely to occur in the nearby villages. The system is part of the recently renewed environmental licences of both terminals. To date, the control of excessive emissions relied on visual inspection, a poor tool, especially at night. The monitoring system is expected to reduce peak emissions and thereby reduce the plants contribution to ambient dust concentrations. Off-line analysis of the data might yield additional information to improve the existing environmental management guidelines in use at the bulk terminals.

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