

# **Dust Emissions from Landfill Deposition: A Case Study in Malmbetget Mine, Sweden**

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## **Abstract**

A great amount of industrial wastes are produced in Sweden every year. In 2008 there were 97.9 million tons of waste generated, among which 93 million tons industrial waste were produced. 64.1% of industrial wastes were deposited in the landfill sites. Dust generation is one of the most important problems associated with industrial waste and landfills. The particulate dust emissions come from the industrial waste may contain heavy metal and produce environmental problems and potential health risks. Active and passive samplers, deposition pans are common equipment to collect dust samples. Real-time monitors use laser diffraction to recording continuous dust concentration. Dust emission from Malmbetget mine in Sweden was analyzed as a case study. Dust was collected by NILU deposit gauge from 26 stations. Generally speaking the amount of dust fallout was decreasing with time because of implemented dust control methods. During the period August 2009 to August 2010, among all the measuring stations through the year, the maximum and the minimum value were 1284 g/100m<sup>2</sup>/30d and 9 g/100m<sup>2</sup>/30d. Two sources of dust generation were identified. The first was located close to the open pit, and the second near the current mining industrial center. The dust generation due to road construction was calculated. On the other hand dust generation was also closely related to weather conditions.

**Keywords:** Depleted Uranium, Weapons of Gulf wars in Iraq, Radioactive waste, Contaminated areas, Health consequences and Environmental problems.

## **1 Introduction**

Sustainable waste disposal may be defined as the transfer of waste from society to nature. There are two routes for this disposal: direct dispersal or landfilling. The generation of waste is a consequence of human activity. Landfill sites have been the most common way

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of eliminating urban solid waste, as well as public and mining wastes. Nevertheless, landfill sites are considered to be authentic biochemical reactors which introduce large quantities of pollutants into the environment such as dust gases, odors and soluble and insoluble substances.

## **2 The History of Landfill in Sweden**

The history of the waste development in Sweden dates from later Swedish Bronze Age (from about 1000BC), the refuse dumps produced from boiling stones and hearths, mixed with other refuse (stone fragments, and other ash or food leftovers). Over the trading period in the Viking time, the waste generation had been increased, and the remains around the settlements in the trading cities grew massively. In the Middle Ages, the waste was mostly dumped anywhere, and it was looked upon as just a practical material handling problem, judging by how it was handled. Until the middle of the 19th century, when an industrial expansion began, Sweden started its sawmill industry changing from the mainly agricultural country. Waste works were built to solve the rapid increasing urbanization and concentration of material flows in the cities, and open burning and dumping in water were still common for waste treatment.

In 1930s, the refuse chute was introduced; the waste reaches the 'packaging age'. Waste management was adapting as well but to a limited extent. Landfills grew in size and numbers and new concern about waste- an environmental interest- developed. From 1940s, it developed for a great step when the cover soil in landfill introduced. The soil cover was designed to reduce the disturbance of rats and unpleasant odors. Later the problems associated with landfill leaching began to attract attentions. Starting in the 1970s; landfill gas emissions had attracted attention, too. In recent years the focus had more and more turned to the processes inside the landfill and their dependency on the quality of the wastes, and in consequence, waste pre-treatment has become a focus of research and development.

With the development of the modern society, the demand of management of the huge amount of the waste from the cities is of great concern for the influence on the environmental, and back to the human health. By the development of the mining industry in Sweden from 1900s, high content of heavy metal contaminated materials had been managed to fulfill the landfill requirement. Therefore, the landfill technology is significantly important in Sweden, due to its consequences on people and the environment [1].

## **3 Landfill Emissions**

The perspective of landfill emissions as a problem had been fundamental for the development of landfill technology. The landfill site formation had become a serious public problem. The results of the research carried by Ritzkowski et al. [2] indicated that the emissions of pollutants, either solid or gaseous, produced in solid urban waste landfill sites, last approximately three decades or even centuries after the landfill site is closed. According to the filling materials, there are two types of landfill: organic materials from

urban areas and construction and tailings from civil engineering and mining industry [3, 4].

Since the spreading of pollution with leachate had been seen as a main problem, the typical recipe during the last couple of decades had been to keep the waste dry and tightly encapsulated and therefore encapsulating techniques had been the subject of numerous studies. In the last decades more long-term solutions had been presented. As example that only waste that has been treated until it has the same properties as earth should be deposited. Why one would want to landfill earth and how such treatment would be possible without large emissions, and highly polluted treatment residuals may be justified questions in this context. Landfill gas had been thoroughly investigated while dust emission was practically left. The time perspective for landfill stabilization can vary between decades up to millennia; depending on the type of waste.

#### **4 The Particulate Dust Emissions**

In mining industry, the source of particulate emissions is from vehicle travel on access roads, topsoil removal and daily cover activities, ongoing construction development, and wind erosion of exposed areas.

Landfilling activities have the potential to produce fine and coarse particulates, the make-up of which will depend on the activities undertaken on-site and the types of waste being handled. Landfilling activities having the potential to generate particulates include:

- a. movement of waste on-and off-site,
- b. handling storage and processing of waste,
- c. plant traffic both on-and off-site,
- d. plant used to burn landfill gas, including gas flare or engines,
- e. dust generated from the surface of the landfill ,erosion.

Exposure to the dust particles that can enter the respiratory system is known to be associated with a range of adverse effects on health. The dust emissions generated in the formation and life of landfill sites because public disturbances as dust particles (smaller than 10 micro in size) penetrate into the organism, from which those smaller than 1 micron are retained in the pulmonary alveoli causing serious diseases.

Dust from landfill sites can become airborne and move off site by a number of mechanisms. The amount of dust lifted from the surface of the landfill is dependent upon the speed of the wind, the condition of the surface and the size of the dust particles. Emissions of dust as a result of wind-blow can be significantly reduced if the surface is wet. If the dust generation has been marked as a problem, the operator should employ dust suppression methods such as surface wetting to avoid the effects of wind-blown.

The distance travelled by dust emissions will depend on the particle size and on the wind speed and turbulence. Smaller dust particles will stay airborne for longer period of time and disperse over a wider area. Strong and turbulent winds will also keep larger particles airborne for longer period of time. The Data reported from quarries indicated that the coarser dust particles (> 30  $\mu\text{m}$ ) are mainly deposited within 100 m of the source intermediate particle (10-30  $\mu\text{m}$ ) between 250m and 500m, while fine particles(<10  $\mu\text{m}$ ) can travel up to 1km. Ultrafine particles (<2.5  $\mu\text{m}$ ) would be expected to travel considerably further[5].

Environmental permits for landfill sites require that dusts must be adequately controlled using, for example, dust suppression measures, so as not to have an adverse impact on

public health. Furthermore, monitoring for particulates is a requirement for the environmental permit. To ensure that there is minimal impact on the local population from nuisance dust issues; regulators should set a nuisance criterion level [6].

Particulates emitted from landfills may also contain metals such as arsenic, cadmium, chromium, cobalt, copper, lead and manganese. Especially for the mining industry, heavy metal in tailings landfill would give significant influences on the environment. It is highly recommended that some good techniques be developed to measure the heavy metal around landfill sites for monitoring the pollution condition around the landfill sites.

## 5 Case Study-Dust Fallout in Malmberget Mine

Malmberget mine operated by Luossavaara-Kirunavaara Aktiebolag (LKAB) is one of the most important iron mines in Sweden. It is located at Gällivare, 75km from Kiruna, and contains some 20 orebodies (figure 1). The mine covers a huge area spreading over approximately 5km from east to west and 2.5 km from north to south. Mining began in 1892, since then over 350Mt of ore had been extracted. In 2006, it produced around one third of LKAB's total production of 23.3Mt of iron-ore products [7]. Surface open pit mining method was firstly used to reach and exploit the ore minerals. A huge pit (figure 2) was abandoned and then large-scale sublevel caving became the predominant mining technology at Malmberget.

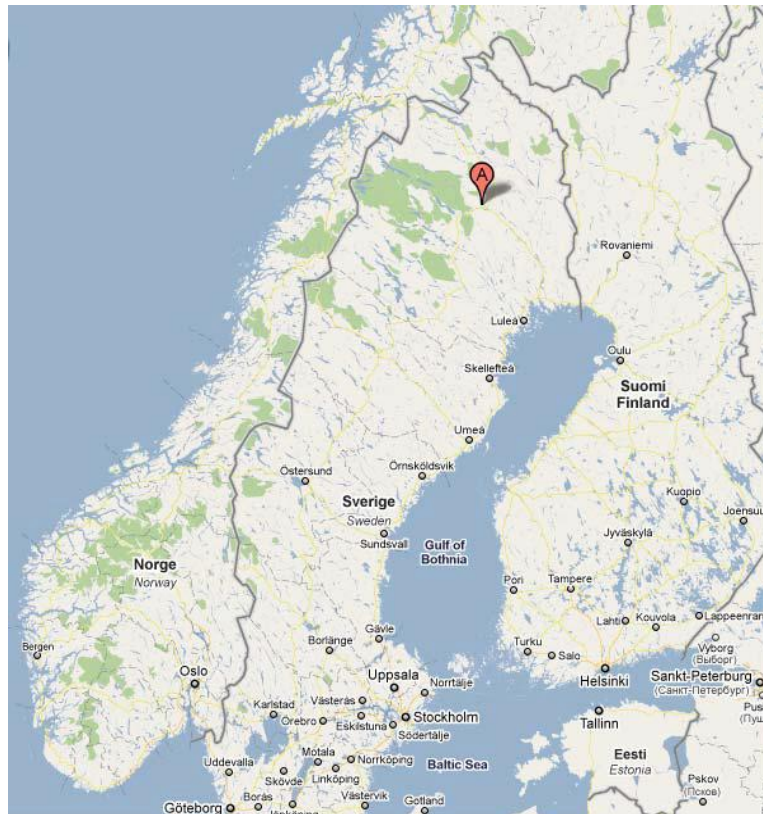


Figure 1: Location of Malmberget mine, Sweden

The land surface features have been deformed due to the underground mining. The surface soil is prone to wind erosion in this bare area after mining. Those who are still living in MalMBERGET and the vicinity complain about elevated dust level due to mining activities. The movement of trucks from the industrial area to dump the debris into the pit enhanced dust generation. However due to some security reasons the filling of the pit was discontinued in March 2009. The LKAB industrial center is located northeast from the open pit, and the main mining operation area includes the open pit area, haul area with stockpile in use, product stockpile area and sedimentation reservoir for used process water (figure 2). There are residential areas located both around the open pit and nearby the LKAB industrial center.

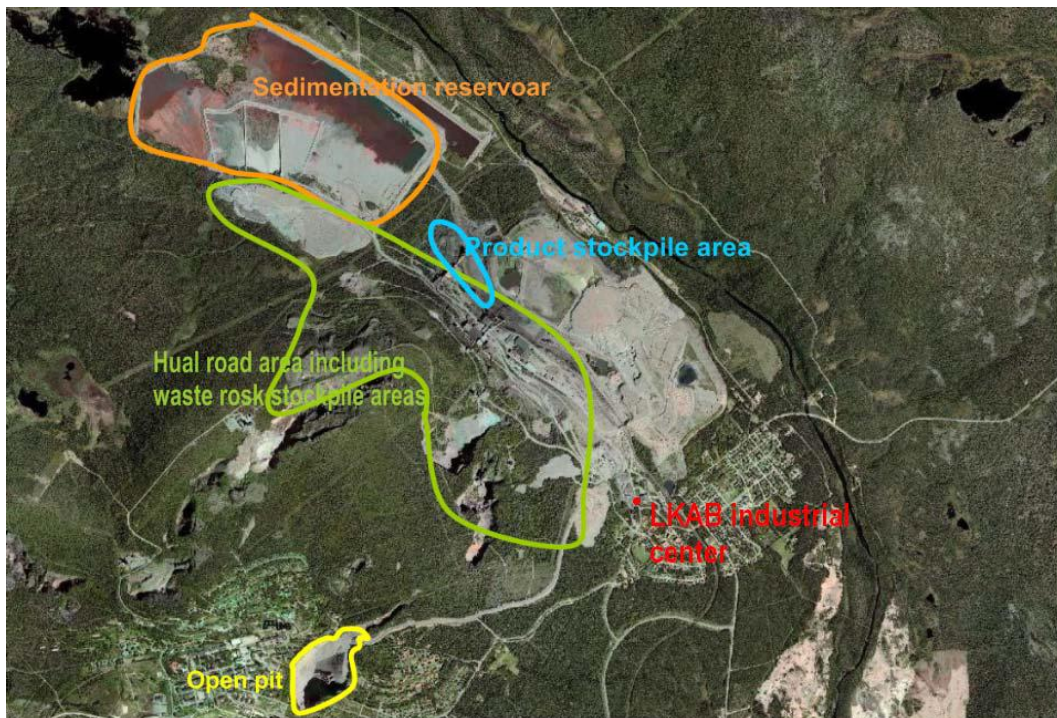


Figure 2: Main operation areas in MalMBERGET mine (from LKAB)

26 measuring stations were installed in the mining site to evaluate the dust problem (figure 3). The dust was collected by a particulate fallout collector produced by the Norwegian Institute for Air Research (NILU) (figure 3). International Standardization Organization (ISO) has considered the collector for adoption as an international reference collector for particulate fallout. The mounting stand is adjustable in height. The collection and weighing of the material was done on approximately a monthly base and reported as  $g/100m^2/30day$ . The systematic data recording started since 2001 but no meteorological monitoring was installed in relation to the dust fallout stations.

Analysis of the data was done using Surfer 9.0 program. This is a contouring and 3D surface mapping program that runs under Microsoft Windows. It can quickly and easily convert data into many types of output including contour, 3D surface, 3D wire frame, vector, image, shaded relief, and post maps.



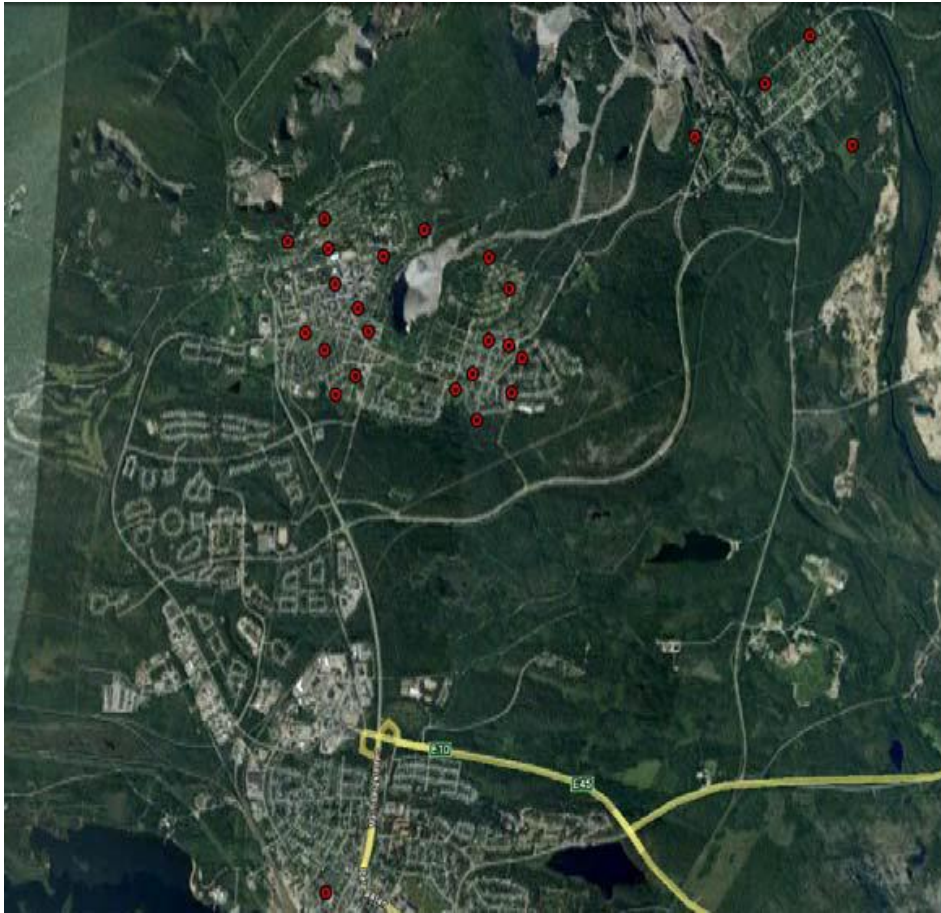


Figure 3: Locations for Dust fallout measuring stations (red dots) in Malmberget mine

The general trend of variation of dust level on the mining site from 2001 to 2010 is shown in figure 4 which shows the yearly average (from August till July the year after) dust fallout. The winter average and the summer average of dust fallout were also calculated and shown in the figure. April, May, June, July and August were considered as summer time and the rest of the months were considered as winter time. Generally speaking the amount of dust fallout was decreasing with time because of some implemented dust control methods such as watering the stockpiles and the haul roads. The slight increase of dust fallout during the year 2009 and 2010 was due to a road construction near the open pit area. More dust was produced by mining activities during the summer than winter due to fact that the climate in the summer is usually very windy and dry and most surfaces are covered by snow during the winter.

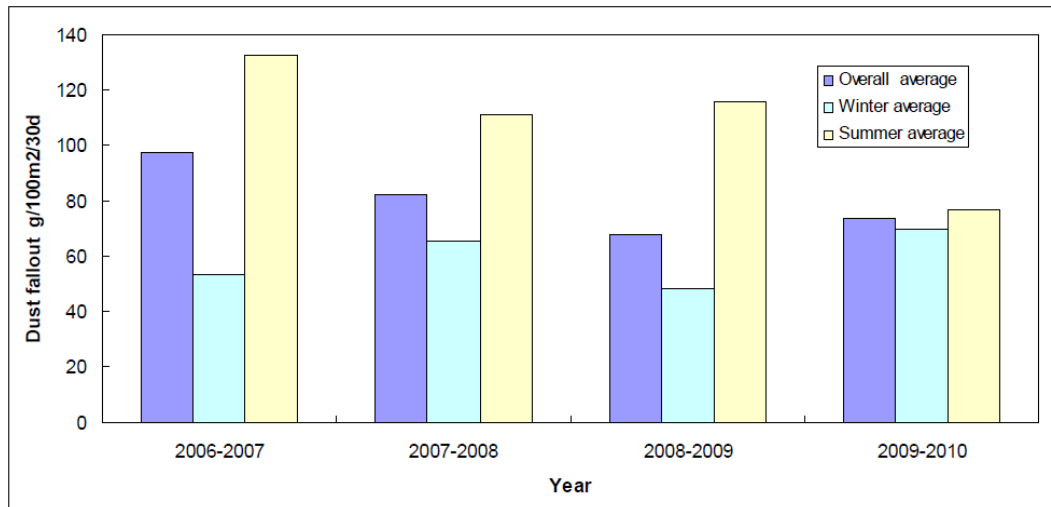


Figure 4: Yearly average, winter average and summer average of dust fallout

The detail of the dust fallout during the year August 2009 to August 2010 analyzed using surfer 9.0 program for the mining area is shown on a contour map of figure 5. Generally the dust production was increased from August 2009 until May 2010 when it reached to the maximum value, and then decreased till August 2010. Two sources of dust generation were identified. The first was located close to the open pit, and the second near the current mining industrial center (figure 5). The relative significance of the two sources was changing with time though the industrial center acted as the dominate source for most of time due to the fact that the main mining operations are taking place in the industrial area. The dust produced from the open pit was much higher in April, May, June and July 2010 than the rest of the months. This was due to a road construction near the open pit at that time. The net dust produced due to the road construction was calculated and is shown in table 1.

Among all the measuring stations through the year, the maximum and the minimum value were 1284 g/100m<sup>2</sup>/30d (station 35, May 2010, figure 3) and 9 g/100m<sup>2</sup>/30d (station 22, December 2009, figure 3) respectively. Both stations were close to the open pit. Looking at the contour lines through the whole year, difference between maximum and minimum dust fallout was over one thousand. However during December 2009 and February 2010 there was a slight decrease in dust fallout.

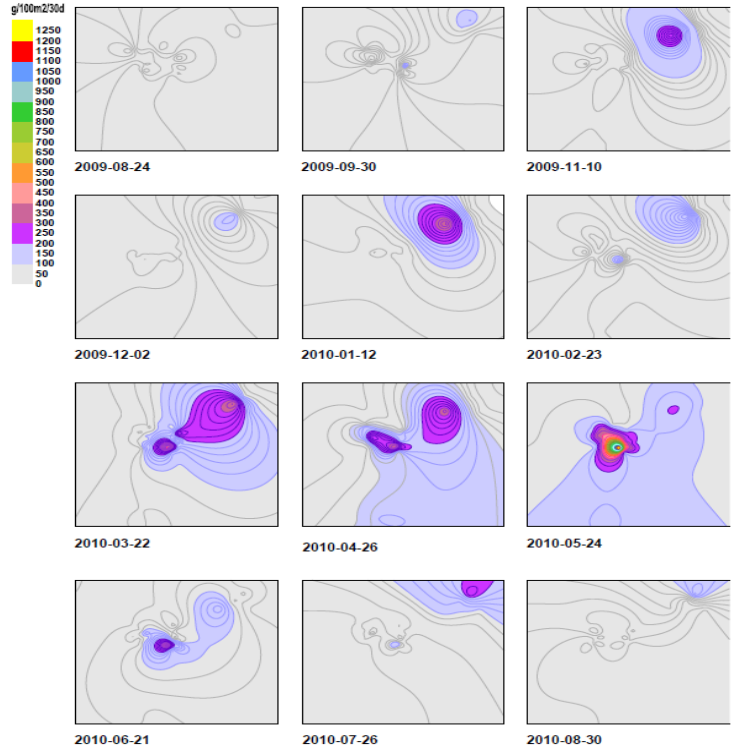


Figure 5: The map of the test area and contour lines for dust fallout from August 2009 to August 2010. (The contour lines were made according to those days when data were available, and the date is shown below each individual figure. The color scale is shown on the top to the right.)

Table 1 Net dust fallout on area A due to road construction

Month	Dust due to road construction activities	
	g/100m <sup>2</sup> /30	
	t/30d	d
2010-04	6.8	89.1
2010-05	11.8	154.1
2010-06	3.2	42.1
2010-07	0.6	8.1



On the other hand, the variation of dust level in the period other than April to July seems to be closely linked with climatic variables such as rainfall, wind speed and humidity. Meteorological data were gathered from Swedish Meteorological and Hydrological Institute (figure 6). During September 2009 the amount of dust was very similar to that in August 2009 despite the fact that the wind velocity was higher in September. This was due to the relatively higher rainfall in that month compared to the previous month. Though the wind velocity decreased in November the dust amount increased due to the lower precipitation and the higher humidity, the later increased particle weight and enhanced settlement. In December the dust emission was relatively low because of the decrease in mining activities due to the Christmas holidays. The increased dusts in January and February in 2010 were mainly due to relatively low rainfall. The combined effect of low precipitation and high wind speed further increased dust emission in March in 2010. In April, May, June and July in 2010 the high dust generation level was mainly caused by the work of road construction. Finally the dust generation in August in 2010 went back to the similar level as it was in August in 2009 as the effect of road construction faded away. Those factors interact with each other and as a consequence one factor can be counter balanced by the other factors, and this leads to the complexity of understanding the dust problem.

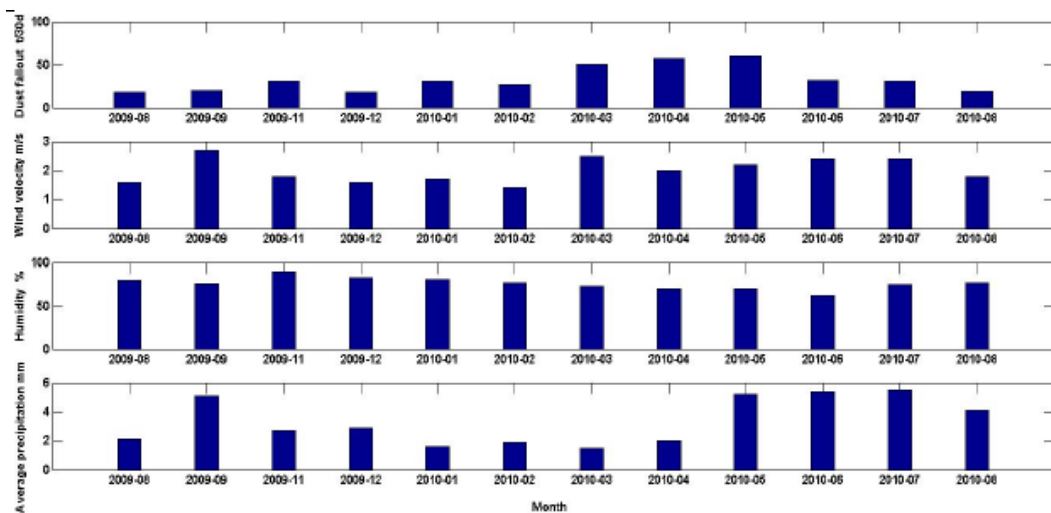


Figure 6: Dust fallout, wind velocity, humidity and precipitation during August 2009 to August 2010

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