ENVIRONMENTAL EFFECTS OF THE OPEN CAST MINING OPERATIONS

AT SAMMAD URBAN AREAS NEAR TO LIMESTONE QUARRIES

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PREFACE

This report is carried out as result of an individual project within the SIDA International Training programme named "Air Pollution mamagement 2009."Advanced International Training Programme".

This programme is conducted by the Swedish Meteorological and Hydrological Institute (SMHI) and sponsored by the Swedish International Development Cooperation Agency (Sida).

The air pollution management program covers different approaches to air pollution management:

- Emission sources and emission inventories.
- Chemical and physical characteristics of air pollution and their cycling in the environment.
- Monitoring and modeling of air pollution.
- Effect of air pollution on human health, agricultures and forestry, materials, etc.
- Technical and structural measures for reduction of emissions.
- International agreement, national legislation and regulations concerning the environment and human health.
- Communication of knowledge, management of change.

This project is the result of one first proposal of our interest and the review, advice and support of the contact personal designed for this specific project, according with his knowledge and experience.

1 EXECUTIVE SUMMARY

Airborne particulate matter represents one of the most pollutant factors in quarrying activities. Particulate matter (PM10) pollution consists of very small liquid and solid particles floating in the air. Of greatest concern to public health are the particles small enough to be inhaled into the deepest parts of the lung. These particles are less than 10 microns in diameter - about 1/7th the thickness of the a human hair - and are known as PM10. This includes fine particulate matter known as PM2.5. PM10 is a major component of air pollution that threatens both our health and our environment,PM10 is among the most harmful of all air pollutants. When inhaled these particles evade the respiratory system's natural defenses and lodge deep in the lungs.

Health problems begin as the body reacts to these foreign particles. PM10 can increase the number and severity of asthma attacks, cause or aggravate bronchitis and other lung diseases, and reduce the body's ability to fight infections.

Although particulate matter can cause health problems for everyone, certain people are especially vulnerable to PM10's adverse health effects. These "sensitive populations" include children, the elderly, exercising adults, and those suffering from asthma or bronchitis.

Of greatest concern are recent studies that link PM10 exposure to the premature death of people who already have heart and lung disease, especially the elderly.

PM10 is often responsible for much of the haze that we think of as smog. This is a problem in our cities, rural areas and pristine areas - such as national parks and forests.[1]

Many areas in Jordan suffering from elevated levels of particulate matter (PM_{10}). One potentially significant source of the observed PM is the resuspension of road dust and dust causes by mining activities in the vicinity of limestone quarries. To obtain data to assess the impact from this source, PM_{10} road dust resuspension factors near Sammad, a town to the west south of Irbid surrounded by many quarries, were measured. Measurements included PM_{10} mass, particle size distributions, wind speed, and wind direction. The results showed that PM_{10} concentrations could be as high as 130 $\mu g/m^3$, and most of the airborne PM is in the coarse fraction. Mining Operations like drilling and blasting, excavation, loading trucks, transportation play a major role in resuspending dust, with an observed PM_{10} emission rate of larger than 130 $\mu g/m^3$.

Comparing the measured concentration of PM10 with the Jordanian standard shows that the concentration acceded in summer season during day work.

Forward trajectories have shown that pollutants attributed to the mining activities inside the quarries, and distributed outside the mining area.

Comparing the measured concentration of PM10 with rainfall shows that the concentration decreases in Winter season during day work.

2 INTRODUCTION AND OBJECTIVES

Natural Resources Authority (NRA) is the only organization in Jordan which is responsible by law to perform geological surveys and to conduct studies in the fields of geophysics, geochemistry, geology, mining, mineral processing and ore dressing.

The main task of NRA is to discover mineral resources and grant permits to companies for mining and utilizing mineral resources. Accordingly, NRA is very vital for activating investment in the mining sector in Jordan.

NRA has continuously developed its technical capabilities over the years; currently NRA needs to develop its capabilities in the aspects of air pollution management specified by precautions and control of the air pollution. So that the NRA looking for resolving this problem.

Jordan has set air quality standards for PM10. Based on health research, these identify acceptable levels of PM10. NRA are now developing, air quality plans to bring PM10 concentrations down to healthful levels. These plans include a variety of programs to reduce emissions , including dust control for roads , mines and quarries .

Jordan has a huge Limestone reserves which used to product aggregates for constructions works, aggregates: - is a mixture of grains resulting from fragmentation of rocks due to crushing and milling industry by different machines, so the sizes ranging between (Powder – Microns) to (10) mm or larger, can be divided into the rubble to two types: coarse aggregate and fine aggregate (microns to few mm).[2]

These reserves are very important economic sector in Jordan, but many of these quarries are located near to urban territories, the mining operation is mainly open cast operations. This activity has fugitive dust sources that contribute to increase air quality levels in the urban areas around the quarries. Figure 1 shows the location of quarries mines areas which distributed in Jordan.[2]

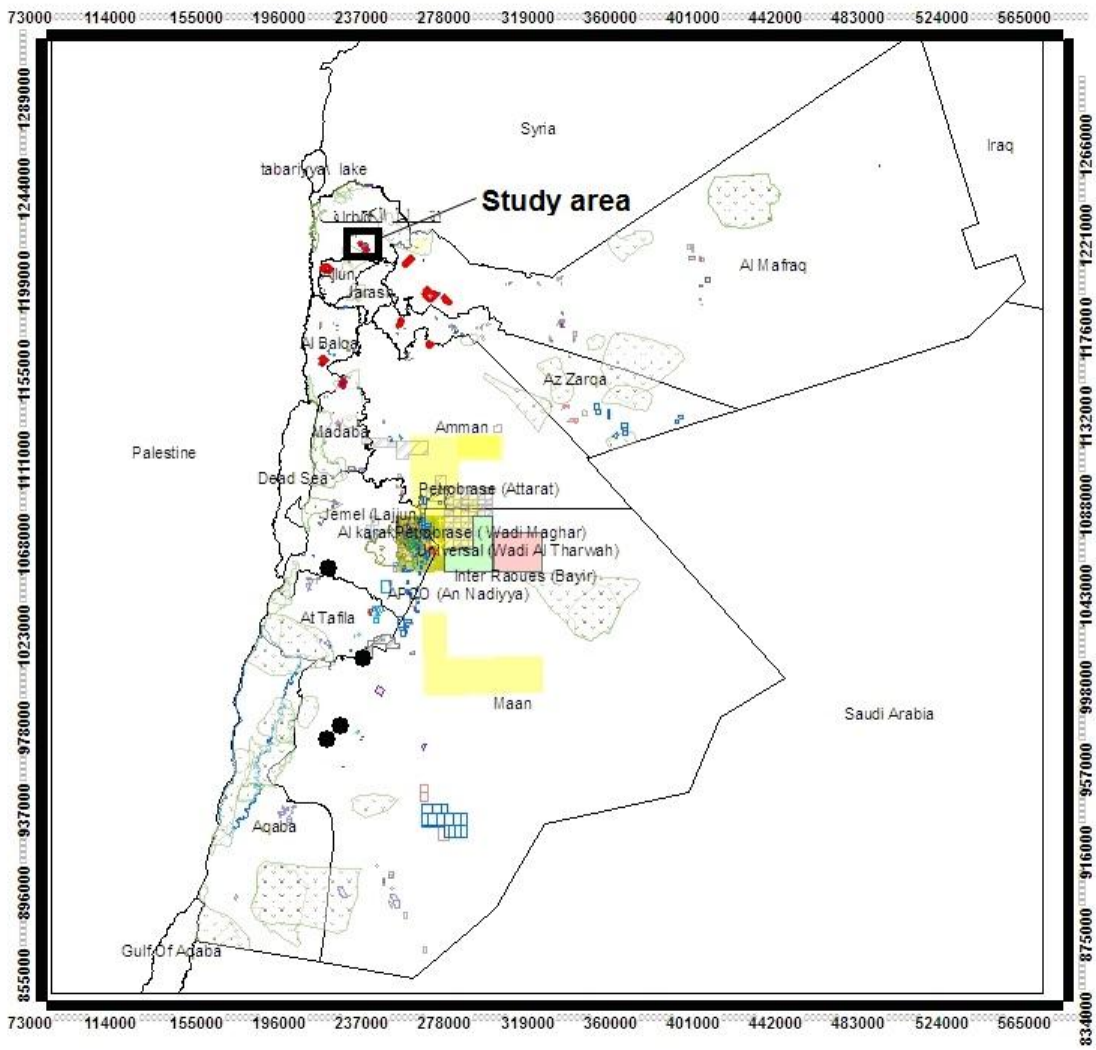


Figure 1. *The location of quarries, mines areas which distributed in Jordan*

Many of the biggest quarries in Jordan which surrounded with urban territories are located in the north of Jordan district Irbid (Sammad area).

This area will increase its production three times of the actual productions levels. In Figure 2 the expected limestone production in Jordan is shown.

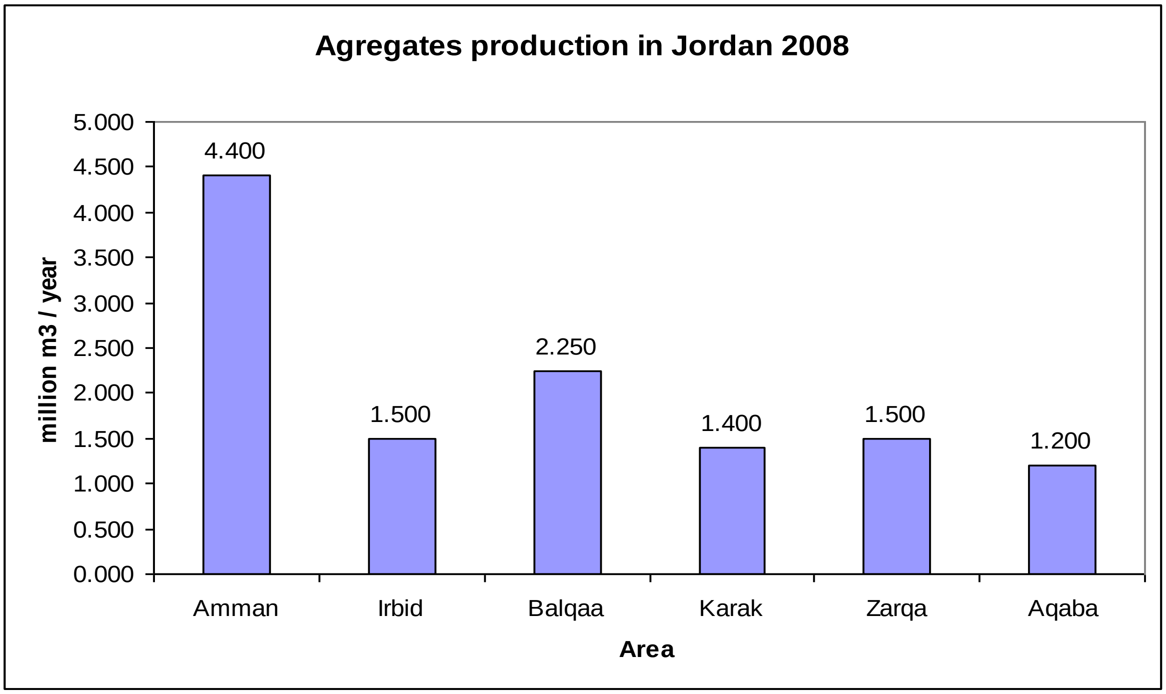


Figure 2.*Expected limestone production in different areas in Jordan.*

Sammad area has a particular conditions and its situation force to analyze different issues:

- All the quarries using different kind of mining operations.
- The limestone transport is made by trucks at public roads.
- There are urban areas near to the mining operations
- The results of privates air quality monitoring by mobile station.

As the mining activity grows, the air quality levels have increased in the mining limestone area. These observations are based on Natural Resources Authority mobile station, which send the results to the Environmental division.

The mining companies and NRA are working together to implement emission reductions and control that produce better air quality levels. To implement these control activities is necessary:

- To know how the behavior of the PM10 into the mining area and the urban area.
- To know how the contributions of each source to the air quality levels.
- To identify which are the sources that contributes mainly to the air quality levels?
- To precise which are the meteorological condition in the area?

Figure 3 shows the limestone quarries locations, the urban areas around them, air quality PM10 mobile stations, and meteorological stations, in Irbid district - Jordan.

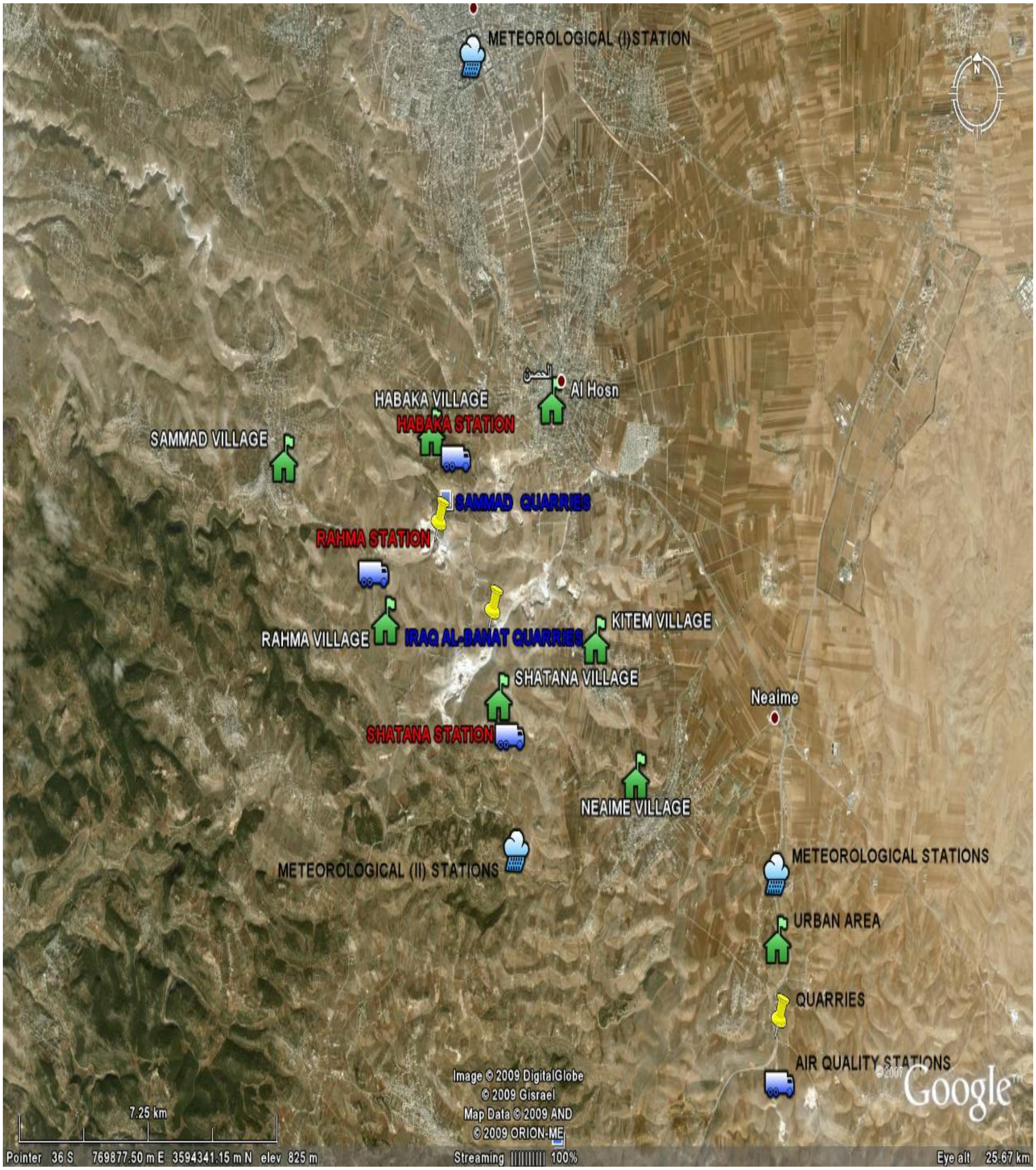


Figure 3.*Limestone quarries Locations, the urban areas around them, Air quality PM10 mobile stations, and meteorological stations, in Irbid - Jordan*

One tool to answer these questions is to develop an air quality dispersion model for these areas. This project work has the following objectives:

- To develop an air quality dispersion model to understand better the impact on air quality due to the limestone mining operations in Jordan
- To evaluate the kindness of adjustment of the model
- To evaluate the kindness of adjustment of the models using different algorithm to calculate two relevant issues in the meteorological information for the model: Stability and mixing layer height.

3. METHODOLOGY

To catch the goal of this project, the methodology adopted was:

Period of analysis	Jan. 2009 to Nov.2009
Origin for all the information	All the information for this project from NRA.
Domain of the analysis	The area that covers all the limestone quarries area and the most important urban areas around them.
Information Air Quality PM10	Information of Mobile station which belong to NRA.
Meteorological Information	Information of Yarmook university meteorological station, Ras-Munif meteorological station, NRA mobile station.
Emission Inventories	Based on the EPA AP-42 emission factors and the amount of activities reported by the Natural Resources Authority and mining companies.

Based on this information we did the following activities:

- Comparing the measured concentrations of PM10 with the Jordanian standard.
- To prepare analysis of trends and correlation between air quality and meteorological stations.
- Using avilable dispersion models for this area (Sammad), then applying the results at the similar areas.
- Put up an air quality dispersion model for some of the mining areas in Jordan and comparing calculated and measured concentrations.Comparing calculated and messured concentrations
- To analyze and discuss the graphics results.

3 RESULTS

3.1 COMPARING THE MEASURED CONCENTRATIONS OF PM10 WITH THE JORDANIAN STANDARD.

- **First area station (Shatana)**

The maximum value of PM10 was 110 µg/m^3 during July, and the minimum value was 50 µg/m^3 during June as shown in figure 4.

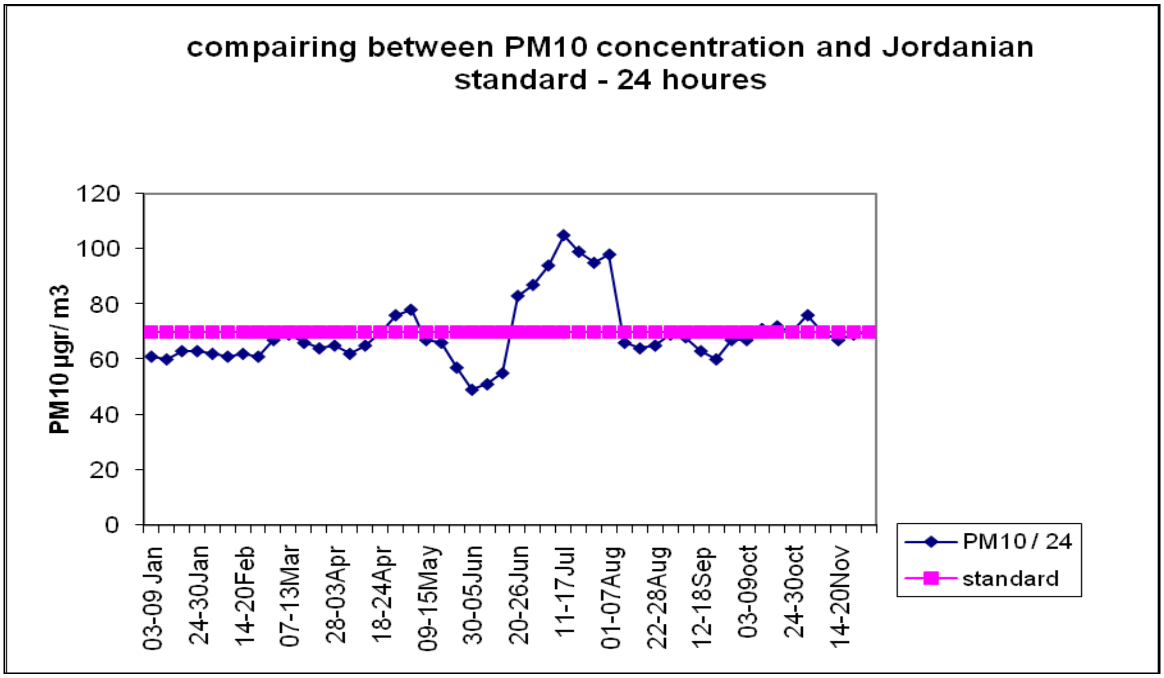


Figure 4 : *comparing the measured concentrations of PM10 with the Jordanian standard at first station area (Shatana) for24 hours*.

During summer season (June – Aug.) The range of PM10 value was (120-140 µg/m^3) , and the value of PM10 during other seasons around the Jordanian standard as shown in figure 5.

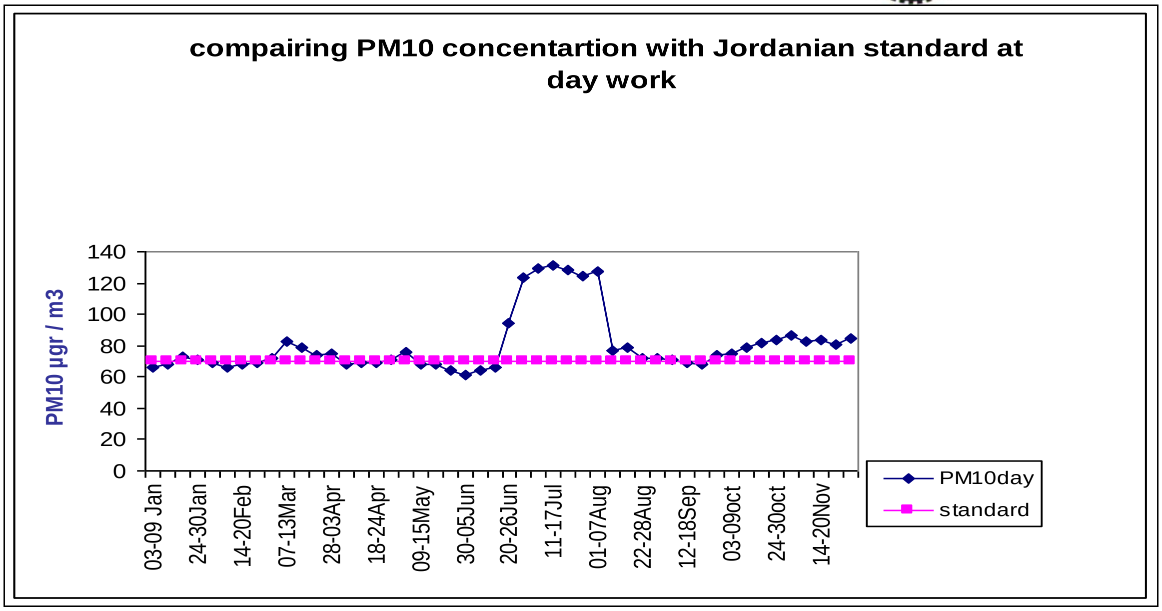


Figure 5 : *comparing the measured concentrations of PM10 with the Jordanian standard at first station area (Shatana) for day work.*

During measured period the concentration of PM10 was below the Jordanian standard except the period from (Jun.- Aug.) as shown in figure 6.

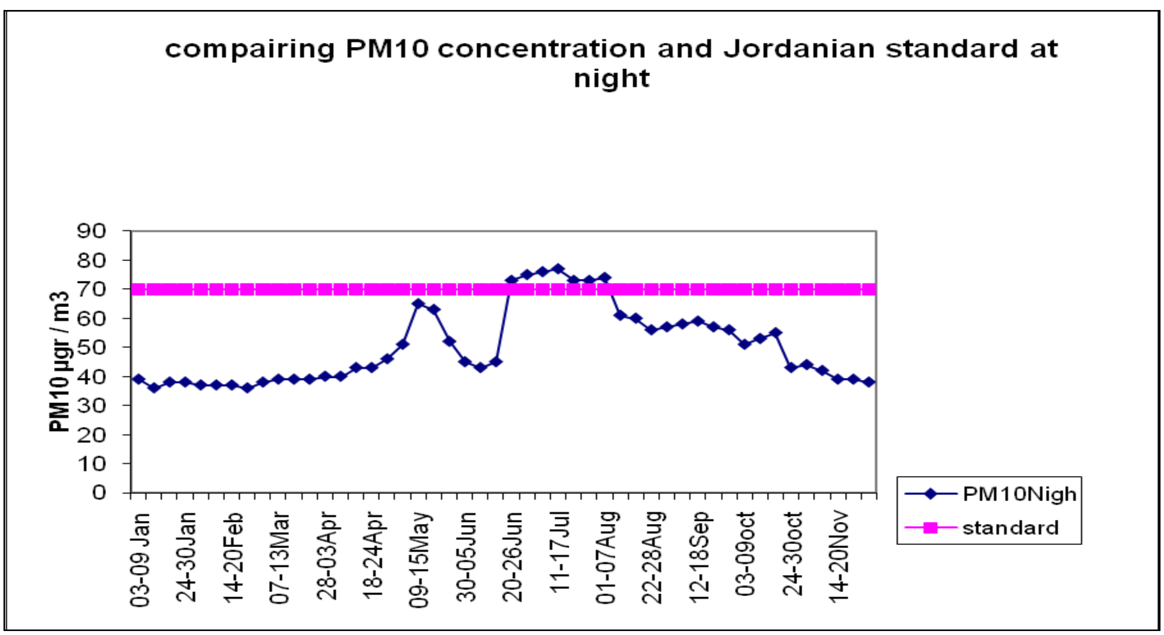


Figure 6 : *comparing the measured concentrations of PM10 with the Jordanian standard at first station area (Shatana) at night.*

- **Second area station (Rahma)**

During the period from (Jan. – Jun.) the concentration of PM10 was below the Jordanian standard, but during the period from (Jun.- Nov.) the concentration of PM10 was above the Jordanian standard as shown in figure 7.

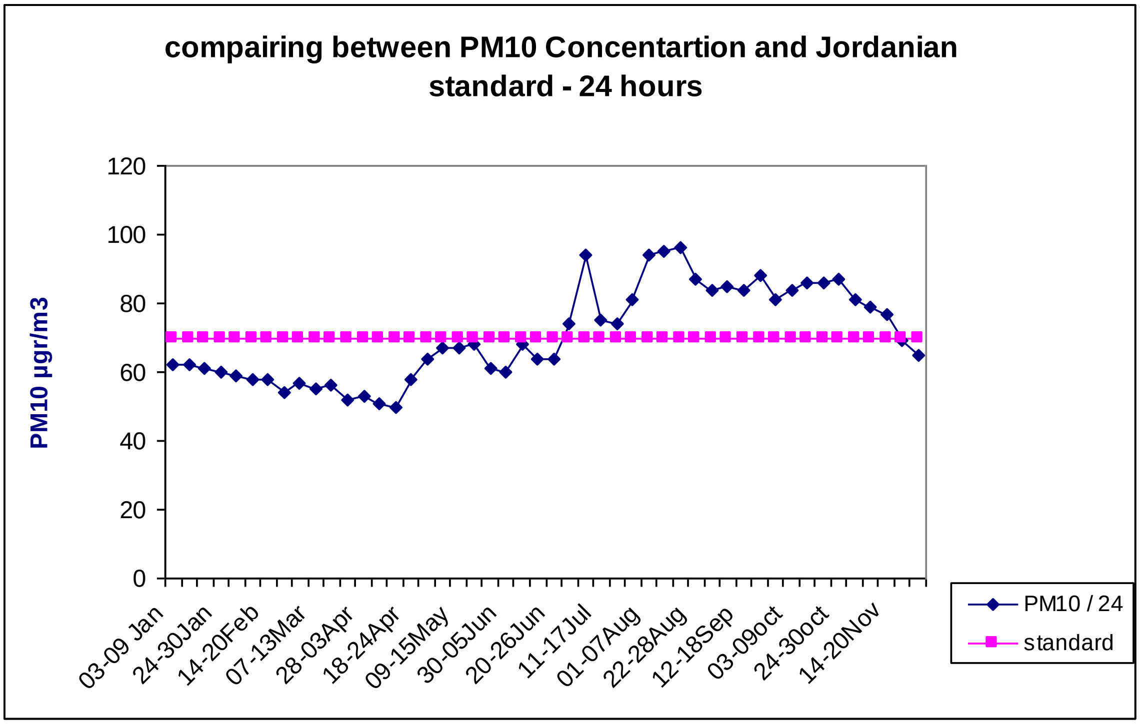


Figure 7: *Comparing the measured concentrations of PM10 with the Jordanian standard at second station area (Rahma) for 24 hours.*

During the period from (Jan. – Apr.) the concentration of PM10 was below the Jordanian standard, but during the period from (Apr.- Nov.) the concentration of PM10 was above the Jordanian standard as shown in figure 8.

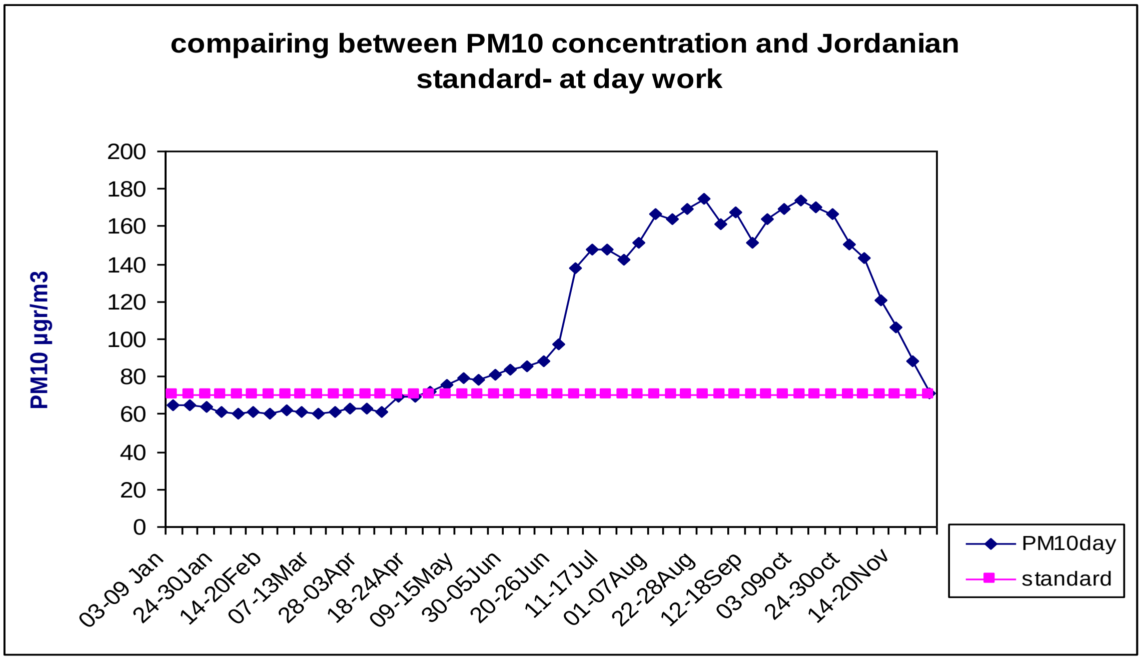


Figure 8 : *comparing the measured concentrations of PM10 with the Jordanian standard at second station area (Rahma) for day work.*

During measured period the concentration of PM10 was below the Jordanian standard as shown in figure 9.

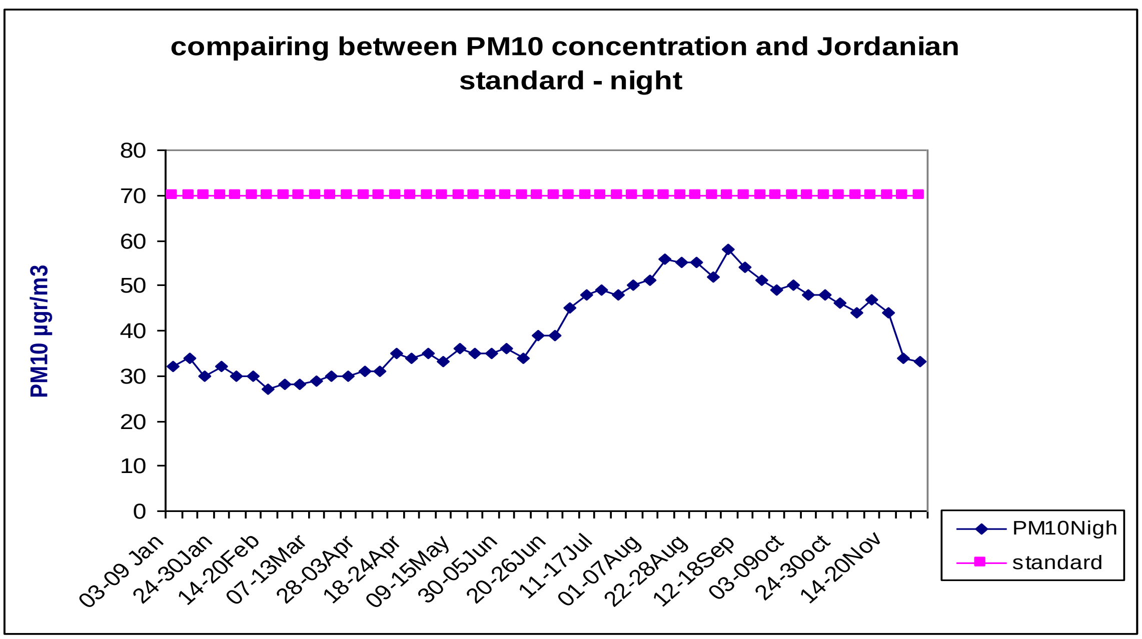


Figure 9 : *comparing the measured concentrations of PM10 with the Jordanian standard at second station area (Rahma) at night.*

3.2 CORRELATIONS BETWEEN METEOROLOGICAL AND AIR QUALITY DATA

3.2.1 WIND ROSES

According to Jordan Meteorology Department, the wind roses for the study area (Sammad limestone mining area) is as shown in figure 10:

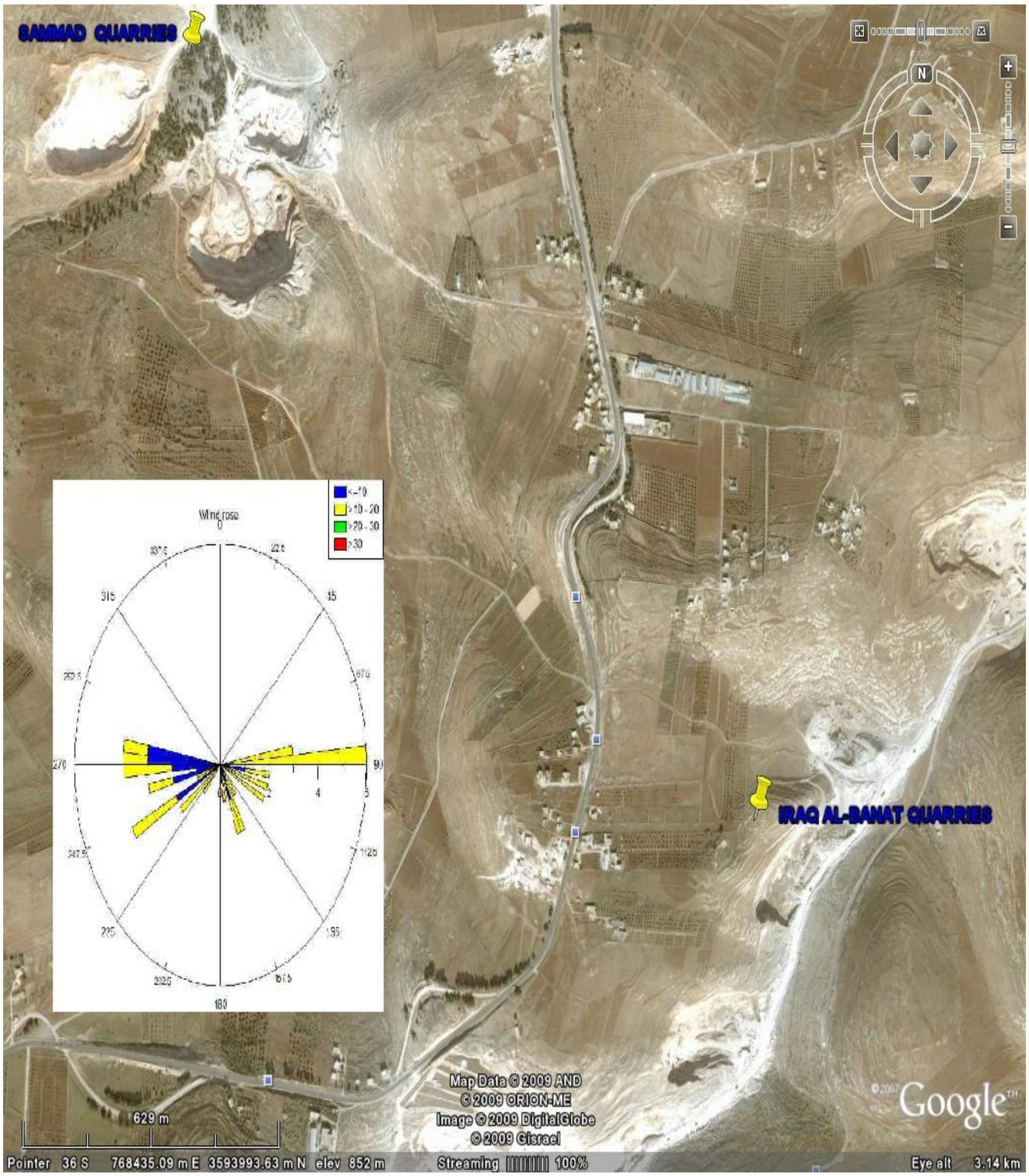


Figure 10: *Wind rose of the study area***.**

3.2.2 TRAJECTORY PLOT OF THE MAXIMUM WEND SPEED.

By using NOAA HYSPLIT MODEL, the result of the forward trajectories have shown that pollutants attributed to the mining activities inside the quarries, and distributed outside the mining area as shown in figure 11:

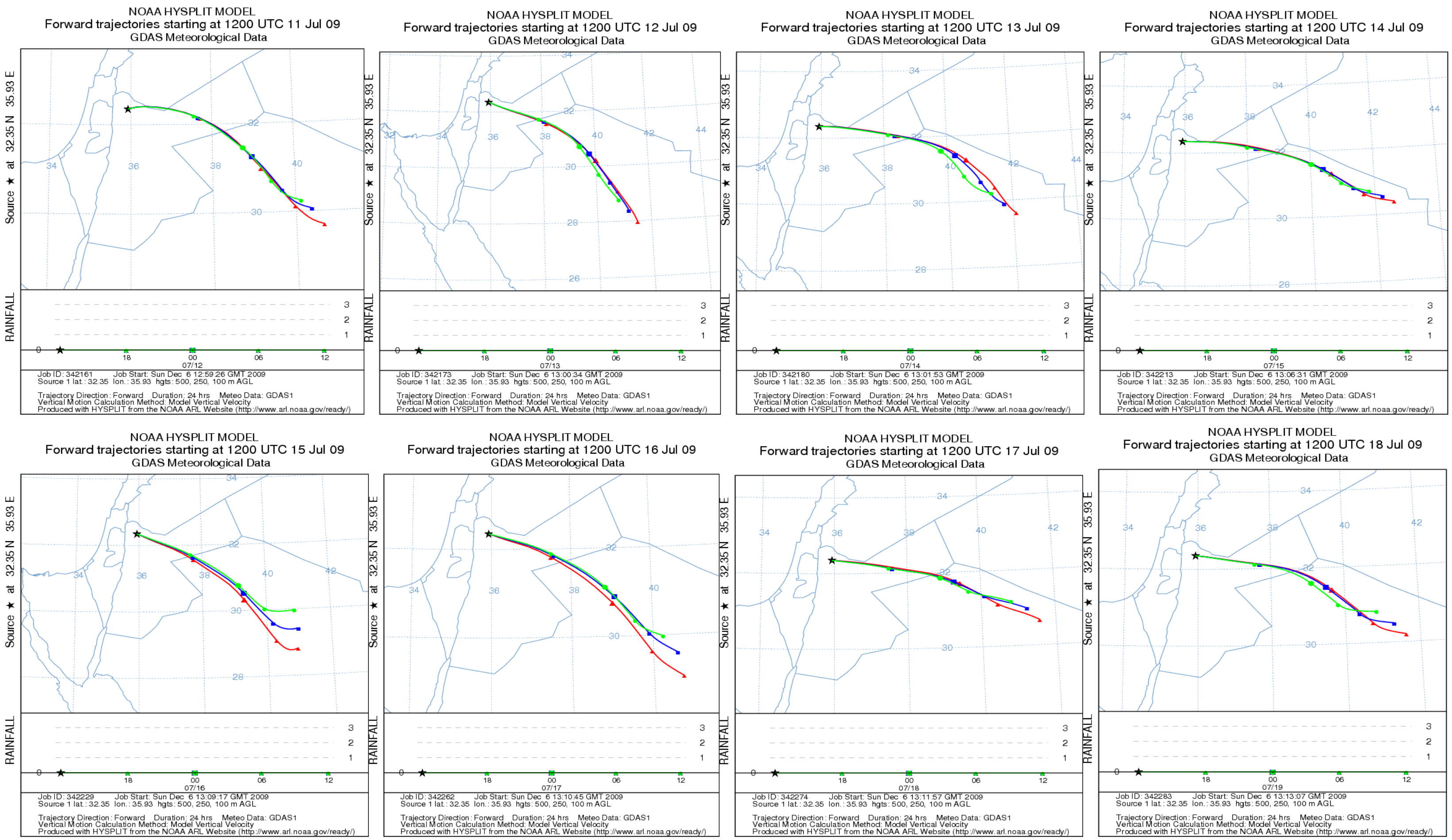


Figure 11: *Trajectory plots of the maximum wend speed.*

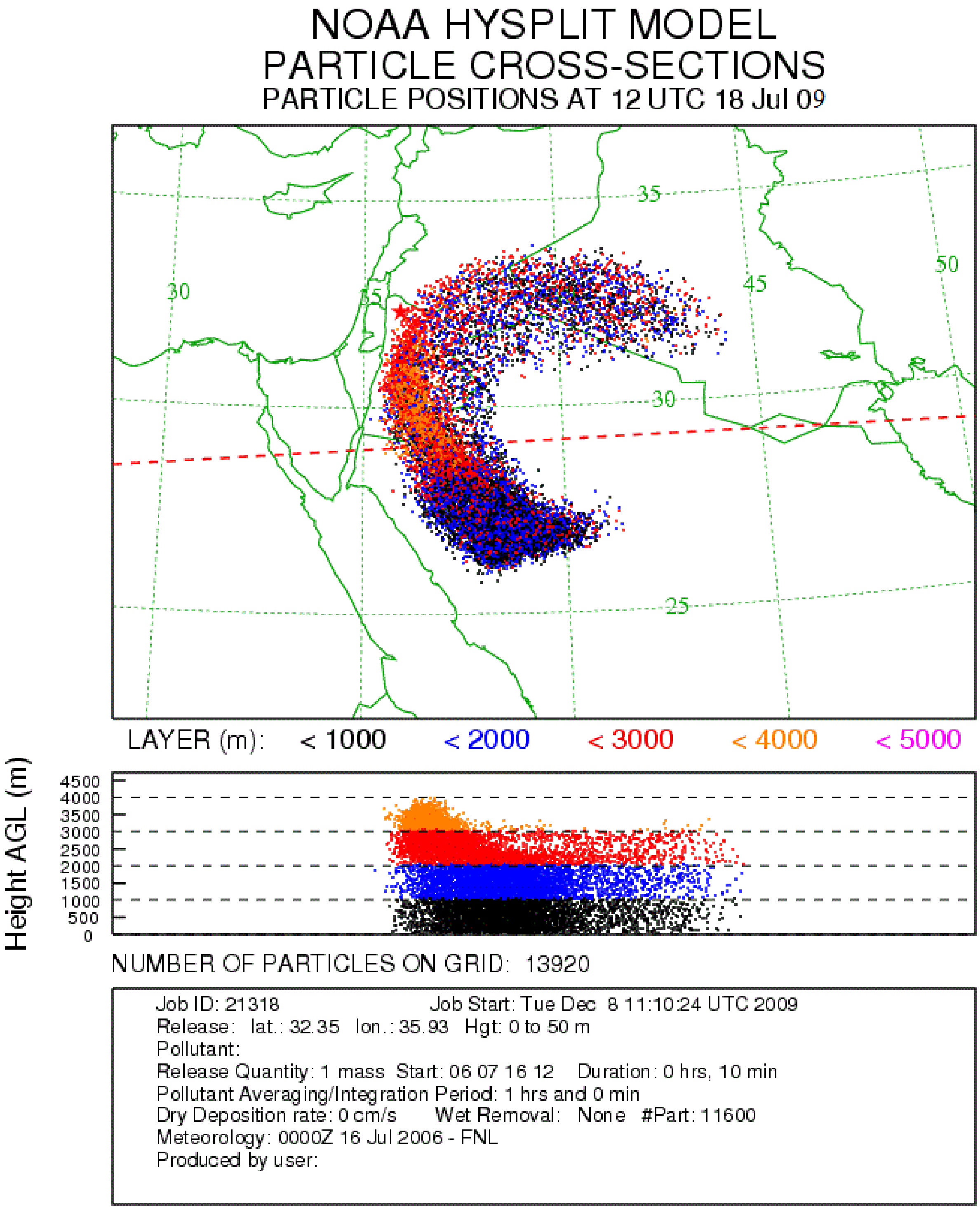


Figure 12: *Trajectory plots of the particle positions at the day 18Jul 09 (summer season).*

3.2.3 TRENDS ANALYSIS FOR WIND SPEED AND CONCENTRATIONS

One hypothesis of this work suggests that there are relations between wind velocity (average and maximum) and air quality levels. To establish this relationship the next figures shows the time series for these variables.

- **First area station (Shatana)**

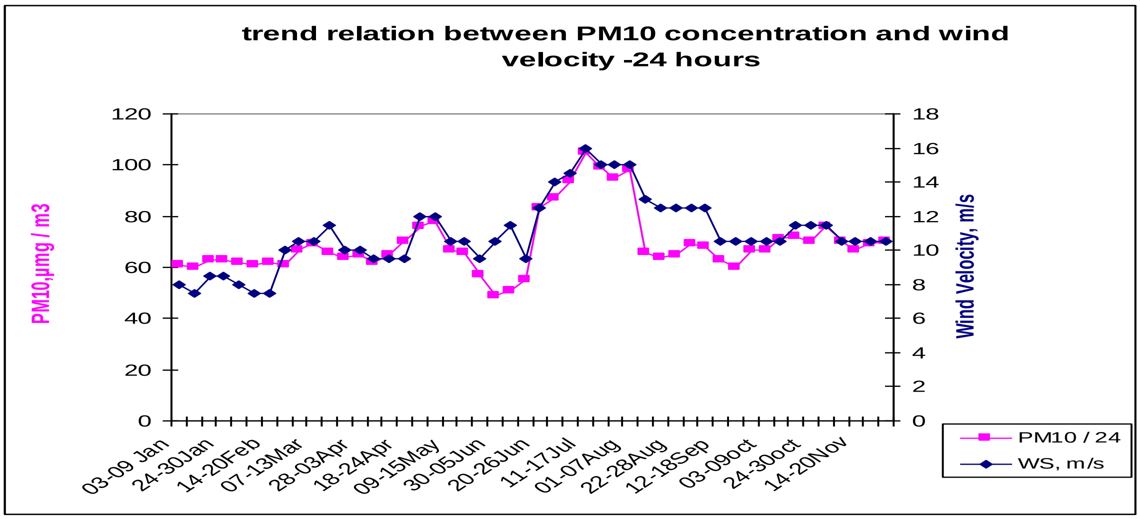


Figure 13: *Trend relation between the measured concentrations of PM10 and wind speed at first station area (Shatana) for 24 hours.*

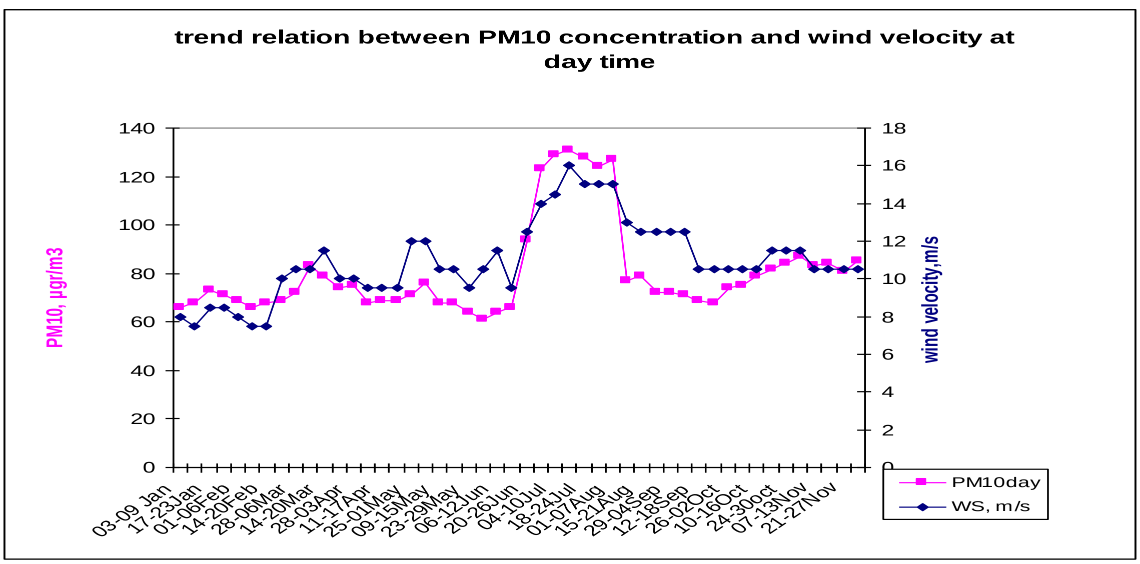


Figure 14: *Trend relation between the measured concentrations of PM10 and wind speed at first station area (Shatana) for day work.*

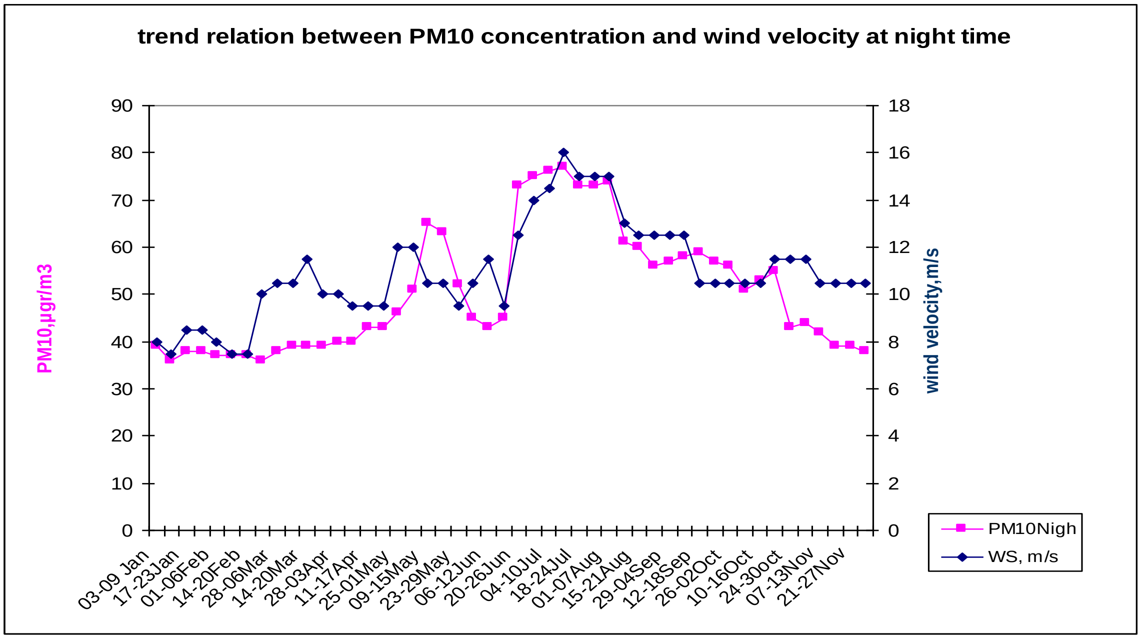


Figure 15: *Trend relation between the measured concentrations of PM10 and wind speed at first station area (Shatana at night.*

- **Second area station (Rahma):**

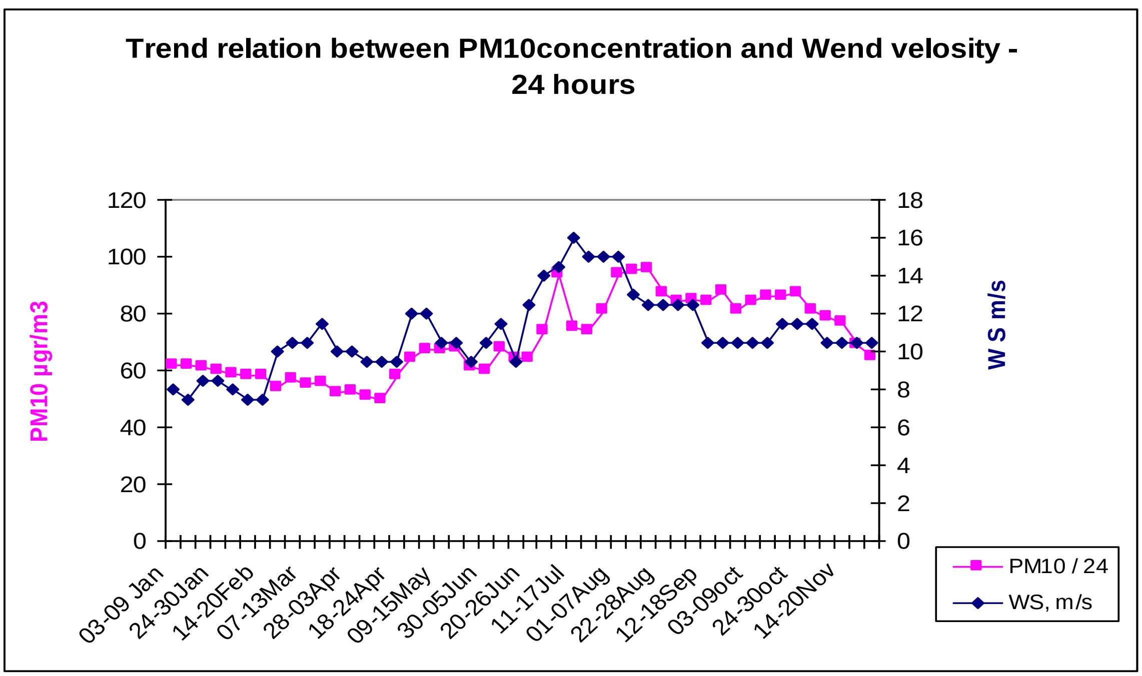


Figure 16 :*Trend relation between the measured concentrations of PM10 and wind speed at second station area (Rahma) for 24 hours.*

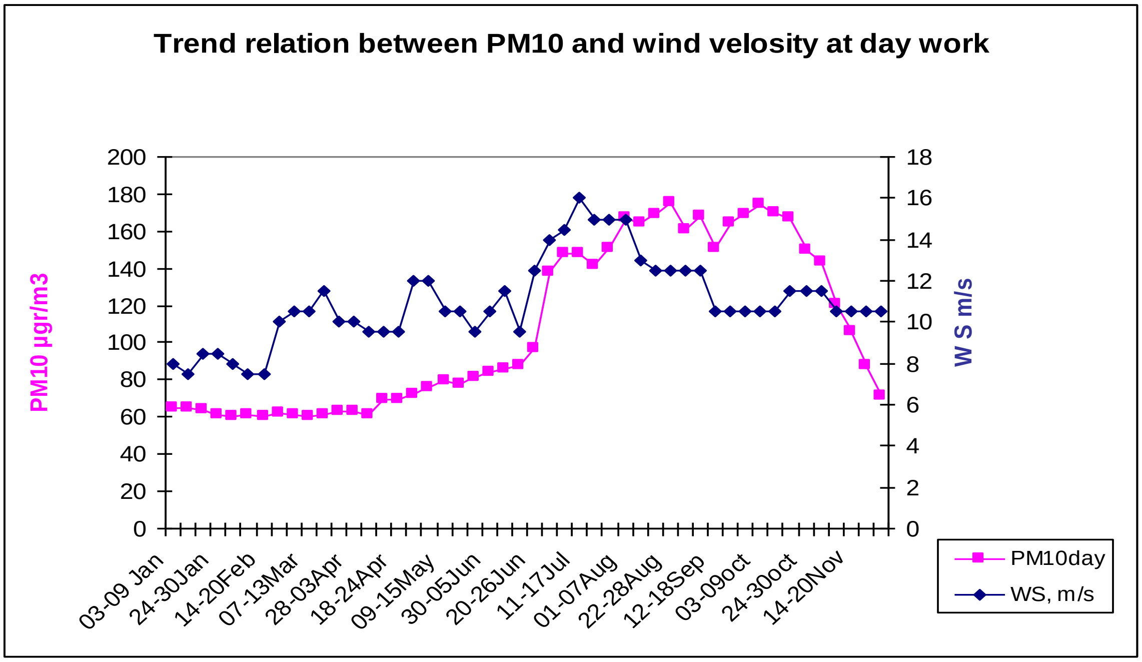


Figure 17 :*Trend relation between the measured concentrations of PM10 and wind speed at second station area (Rahma) for day work.*

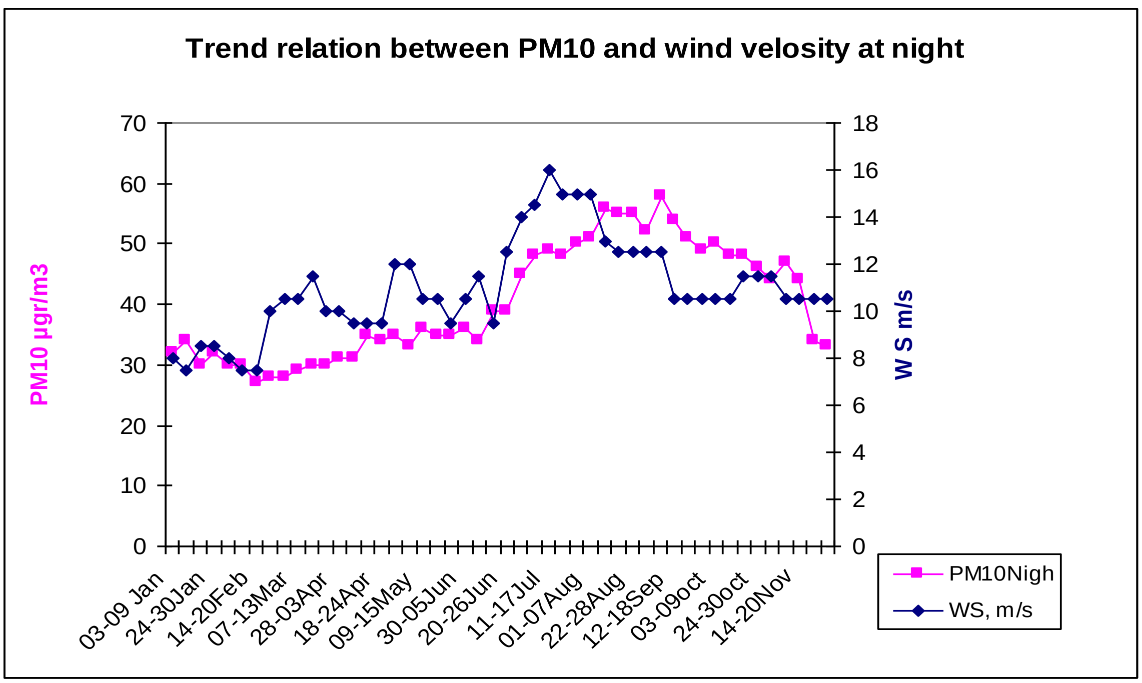


Figure 18: Trend *relation between the measured concentrations of PM10 and wind speed at second station area (Rahma) at night.*

3.2.4 Trends analysis for Rainfall and air quality

Open mine operations have fugitive dust sources mainly, and the emission depends of the humidity and the control. Furthermore, the emission has a high percentage of particulate matter. The rain is a natural control mechanism, especially for coarse material, and many studies show that this "natural control" must be included in the emission factors calculations and in the washout removal mechanism into the atmosphere.

The following graphics show the trends and relations between the rainfall and the concentrations average.

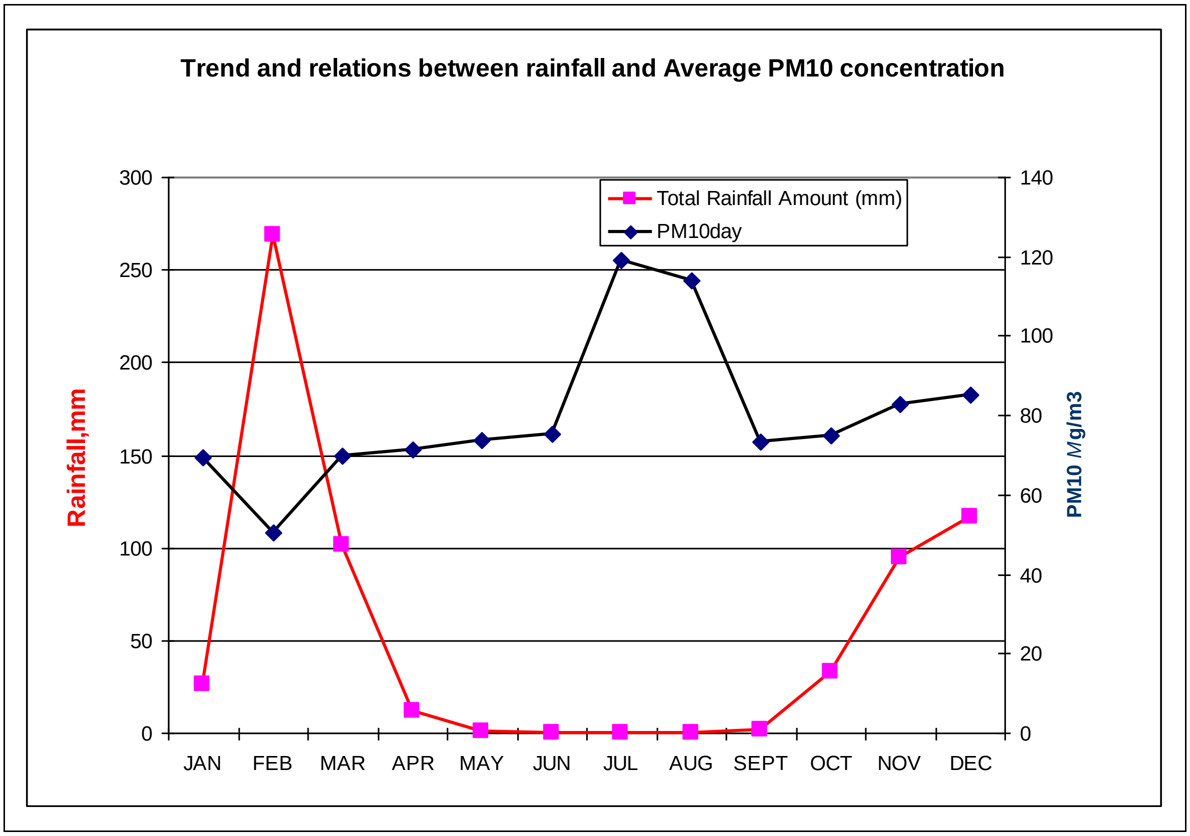
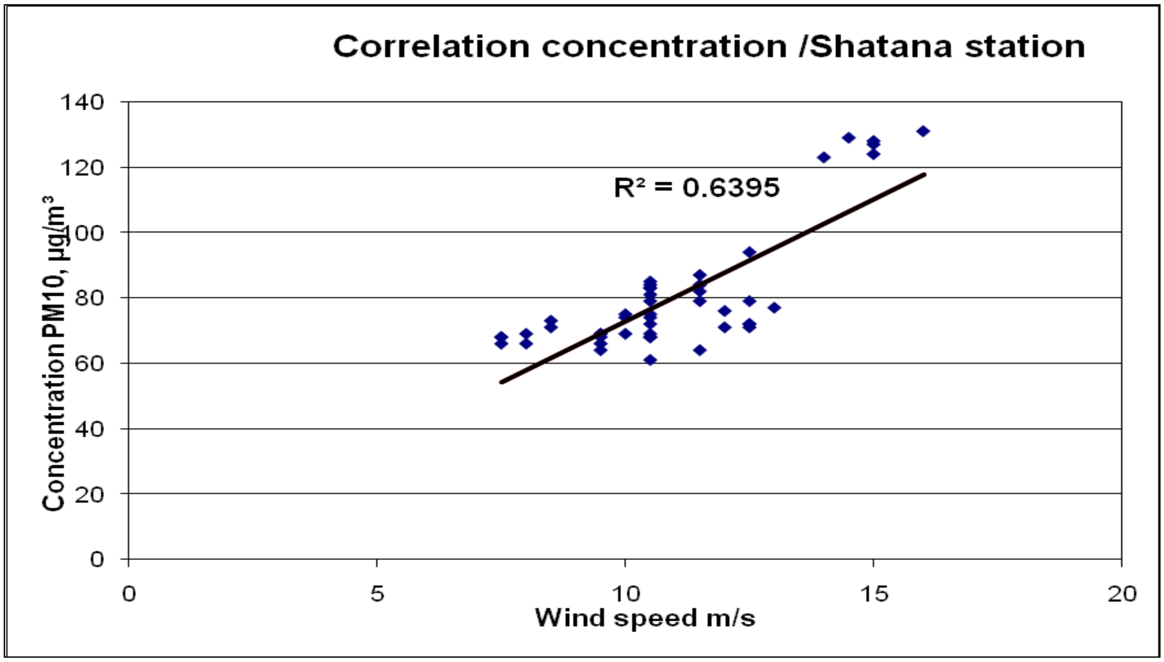


Figure 19: *Trend and relation between rainfall and the concentrations of PM10.*

3.2.5 Correlation analysis for average wind speed and concentrations

The next graphs show the **R** correlation factor for the wind speed and concentrations.



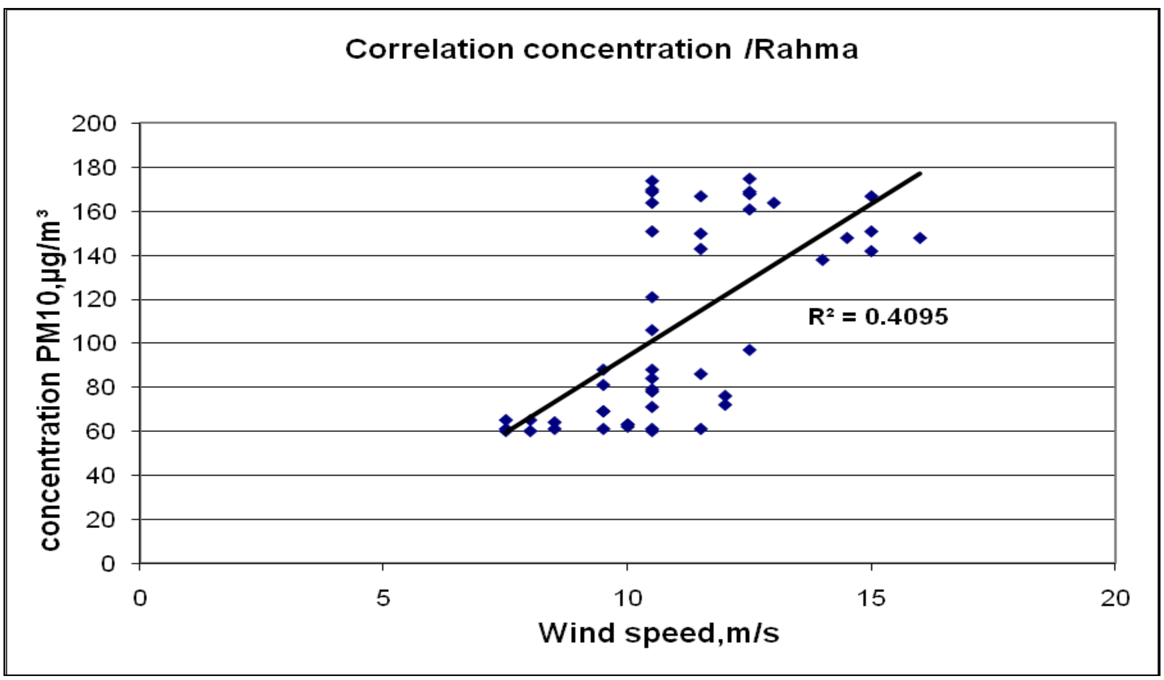


Figure 20 :*Correlation concentration of Shatana and Rahma.*

3.2.6 Sources

The mining operation was classified in the following activities:

SOURCE: PIT	
PIT1	Drilling
PIT2	Blasting
PIT3	Sterile Loading
PIT4	Load of conveyor system
PIT5	transit of waste trucks
PIT6	Waste operations of auxiliary equipment
PIT7	Limestone loading
PIT8	transit of limestone trucks
PIT9	transit of light duty vehicles
SOURCE: WASTE AREAS	
BOT1	Sterile truck unloading
BOT2	Sterile conveyor unloading
BOT3	Bulldozing of waste areas
BOT4	Wind erosion of exposed areas
BOT5	transit of sterile trucks on the waste area
SOURCE: LIMESTONE YARD	
PAT1	Limestone truck unloading
PAT2	Limestone unloading to conveyor
PAT3	Bulldozing of limestone
PAT4	Truck loading
PAT5	Wind erosion of limestone yard
PAT6	transit of limestone trucks on the limestone yard
SOURCE: ROADS	
VIA1	Transit road pit - waste area
VIA2	Transit limestone road Pit Limestone Yard
VIA3	Light duty transit on surrounding roads

3.2.7 Emissions

To calculate de emissions were used the emissions factors of document EPA-AP42. The factors used for each activity are:[3]

SOURCE		NAME OF EMISSION FACTOR	REFERENCE
SOURCE: PIT			
PIT1	Drilling	Drilling	AP-42 Table 11.9-4
PIT2	Blasting	Blasting	AP-42 Table 11.9-2
PIT3	Sterile Loading	Storage Piles	AP-42 Section 13.2.4.
PIT4	Load of conveyor system	Bulldozing	AP-42 Table 11.9-2
PIT5	transit of waste trucks	Unpaved Roads	AP-42 Section 13.2.2.
PIT6	Waste operations of auxiliary equipment	Bulldozing	AP-42 Table 11.9-2
PIT7	Limestone loading	Truck loading	AP-42 Table 11.9-2
PIT8	transit of limestone trucks	Unpaved Roads	AP-42 Section 13.2.2.
PIT9	transit of light duty vehicles	Unpaved Roads	AP-42 Section 13.2.2.
SOURCE: WASTE AREAS			
BOT1	Sterile truck unloading	Storage Piles	AP-42 Section 13.2.4.
BOT2	Sterile conveyor unloading	Storage Piles	AP-42 Section 13.2.4.
BOT3	Bulldozing of waste areas	Bulldozing	AP-42 Table 11.9-2
BOT4	Wind erosion of exposed areas	Wind erosion of exposed areas	AP-42 Table 11.9-2
BOT5	transit of sterile trucks on the waste area	Unpaved Roads	AP-42 Section 13.2.2.
SOURCE: LIMESTONE YARD			
PAT1	Limestone truck unloading	Storage Piles	AP-42 Section 13.2.4.
PAT2	Limestone unloading to conveyor	Storage Piles	AP-42 Section 13.2.4.
PAT3	Bulldozing of limestone	Bulldozing	AP-42 Table 11.9-2

PAT4	Train and truck loading	Storage Piles	AP-42 Section 13.2.4.
PAT5	Wind erosion of limestone yard	Active Storage Piles	AP-42 Table 11.9-2
PAT6	transit of limestone trucks on the limestone yard	Unpaved Roads	AP-42 Section 13.2.2.
SOURCE: ROADS			
VIA1	Transit road pit - waste area	Unpaved Roads	AP-42 Section 13.2.2.
VIA2	Transit limestone road Pit Limestone Yard	Unpaved Roads	AP-42 Section 13.2.2.
VIA3	Light duty transit on surrounding roads	Unpaved Roads	AP-42 Section 13.2.2.

4 DISCUSSION

- ❖ By comparing the measured concentrations of PM10 with the Jordanian standard at first station area (Shatana)The previous graphics shows:

1. With recording the data 24 hours

- During the winter season the concentration of PM10 is equal or below the Jordanian standard.
- During summer season the concentration of PM10 is over the Jordanian standard.

2. With recording the data at day work (from 6 am to 6 pm)

- From 7 March to 3 April the concentration of PM10 over the Jordanian standard (with about 10 µg/m^3).
- In summer season the concentration of PM10 over the Jordanian standard (with more than 50 µg/m^3).
- From October to December the concentration of PM10 rise a little over the Jordanian standard.
- Other seasons the concentration of PM10 is equal or below the Jordanian standard.

3. With recording the data at night.

- As shown in the graphic the concentration of PM10 over the Jordanian standard only in summer time (June - July).

- ❖ By comparing the measured concentrations of PM10 with the Jordanian standard at first station area (Rahma) the previous graphics shows:

4. With recording the data 24 hours

- During the winter season the concentration of PM10 is equal or below the Jordanian standard (January to May, and December).
- During summer season the concentration of PM10 is over the Jordanian standard from May to November).

5. With recording the data at day work (from 6 am to 6 pm)

- During summer season the concentration of PM10 over the Jordanian standard (from April to November).
- During winter season the concentration of PM10 below the Jordanian standard (from December to April).
- From November the concentration of PM10 starting decreases.

6. With recording the data at night.

- As shown in the graphic the concentration of PM10 below the Jordanian standard during the year.

❖ Analysis Trend relation between the measured concentrations of PM10 and wind speed at both stations area (Shatana and Rahma) for 24 hours, day work and at night.

As shown in figure 13,14,15,16,17,18 the trend relations between the measured concentrations of PM10 and wind speed, when the wind speed increases the concentrations of PM10 decreases in winter season, but in summer season when the wind speed increases the concentrations of PM10 increases.

❖ Analysis Trend and relation between rainfall and the concentration of PM10.

- The relation between the rainfall and the average concentration of PM10 (as shown in figure 18) shows that when the rainfall increases the concentration of PM10 decreases (Inverse relation), it is shows clearly during summer season.

❖ Graphic 20 shows the **R** correlation factor for the wind speed and concentrations.

- Correlation concentration of Shatana station – $R^2 = 0.6395$.
- Correlation concentration of Rahma station – $R^2 = 0.4095$.

5 CONCLUSIONS

Dust has effect on the health and safety of workers in mines and residents living in the urban areas near to these mines, as well as biodiversity in the region. Monitoring and follow-up measurements of dust levels in the atmosphere are important elements to preserve the environment, this gives the importance of this study, to control the dispersion of dust(PM10), where we were monitoring Pm10 During the period between January - November 2009, the result of analysis of information as follows:

- Comparing the measured concentration of PM10 with the Jordanian standard shows that the concentration acceded in summer season during day work.
- Forward trajectories have shown that pollutants attributed to the mining activities inside the quarries, and distributed outside the mining area.
- Comparing the measured concentration of PM10 with rainfall shows that the concentration decreases in Winter season during day work

6 RECOMENDATIONS

There are some procedures can do to reduce the threat of PM10:

1. Drive slowly on unpaved roads, and to spray water at this roads .
2. Get involved with air quality improvement programs in the urban areas near to Sammad and other similar areas.
3. owners of quarries which causes the pollution of PM10 , comply with local rules that apply to their operation. Work with local agencies to develop strategies that will further reduce PM10 emissions.

References

1. Air resources board,air pollution particulate matter Brochure,general information, http://www.arb.ca.gov/html/brochure/pm10.htm.

2. general information , Natural Resources Authorty.

3. U.S. Environmental Protection Agency (EPA), AP 42 Section 11.19.2 emission factors.Crushed Stone Processing and Pulverized Mineral Processing, Update 2004, August 2004 (PDF 63K).