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Assessment of Particulate Matter (PM) Emitted by Cement Industry: A Case Study in Shahroud

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ABSTRACT
Cement industry is flourishing in Iran due to the rapid population growth, the change in living style and the availability of raw material in the region. The increase of cement factories and their associated quarries in the region may deteriorate air quality and thus threaten the fragile ecosystems in the region. This study presents predictions of particulate matter emitted from a modern cement plant that is constructed in Shahroud, Iran. AERMOD is used to carry out the modeling part of this assessment. Our findings indicated that concentrations of Particulate Matter (PM) were found to be well below the permissible Iranian and EPA Standards for ambient air quality. Therefore, the proposed activity is not likely to have any significant adverse impact on the air environment in the vicinity of industry. However, The PM concentration is expected to be high according to the National standards approved in 2012.

Key words: Shahroud, cement, particulate matter, AERMOD

INTRODUCTION
The cement industry contributes significantly to the imbalances of the environment; in particular air quality. The key environmental emissions are nitrogen oxides (NO_x), sulphur dioxide (SO_2) and grey dust (Albeanu *et al*., 2004). Industrial plant smokestacks from cement and construction companies are some of the biggest contributors to poor air quality, especially in urban developments. As of 2007, the cement industry alone was reported to produce 5% of total greenhouse gasses in the atmosphere (AQR, 2011). The principal aim in pollution control in the cement industry is to minimize the increase in ambient particulate levels by reducing the mass load emitted from the stacks, from fugitive emissions and from other sources (Ehrlich *et al*., 2007). The World Health Organization states that 2.4 million people die each year from causes directly attributable to air pollution (Meo *et al*., 2013). Epidemiological studies suggest that more than 500,000 people die each year from cardiopulmonary disease linked to breathing fine particle air pollution (WHO, 2007). Air pollution has potentially harmful or nuisance effects on human beings, animals, plants, their biological communities and habitats and on the soil (Karbassi *et al*., 2008). The objective of this study is to present an assessment of the emissions from the cement plant, which is constructed at Semnan province, located about 15 km north of Shahroud city, Iran. This plant produces 2700 tons per day in their recently upgraded 63 m kiln. Extension plans include the

inauguration in 2007 of a second kiln which will add 3400 tons of production capacity and make Shahroud Cement Company one of the largest cement plants in Iran. In our study, the predicted emissions emitted from cement plants were compared with the EPA standards of ambient air quality to check their compliances. Special attention has to be paid to any proposed activities in regions in order to minimize the environmental consequences of dust accumulated on shrubs and herbs, which may lead to their death and thereby destroy the fragile ecosystem there in.

MATERIALS AND METHODS

Climatology: Shahroud has a semi-arid climate climate characterized by extreme cold and dry winters and mild summers with the low relative humidity. Rainfall is slightly irregular, with the exception of occasional cloudbursts that can cause flash flooding when they occur. Temperatures may rise above 40°C during the summer season. Average characteristics of recorded weather data shows that the average annual rainfall and average annual temperature in the region are 166.6 mm and 14.8°C, respectively. The collected data on the wind speed and direction were analyzed and wind rose was drawn. Figure 1 depicts the wind rose of the region. As can be seen, the prevailing wind is north east winds that started in March and its speed and intensity incresed gradually and it reaches its maximum in summer.

Input data required by the model: The AERMOD software air quality is used to evaluate the concentration of dust emissions from the cement plant area in the ambient air above the ground level. AERMOD model is designed to determine air pollutant concentration in a variety of land, from flat plains to rugged mountains. Pre-processor AERMAP in AERMOD model is designed for the desired topographic information processing and data preparation of the selected land. The pre-processor determines the altitude below all receptors and resources and the scale height for each recipient which has the most effect on the dispersion of pollutants in the acceptor.

One of the requirements of this model is the input file that contains the desired options for the model as well as information about the sources of emissions and receptor status. Moreover, two

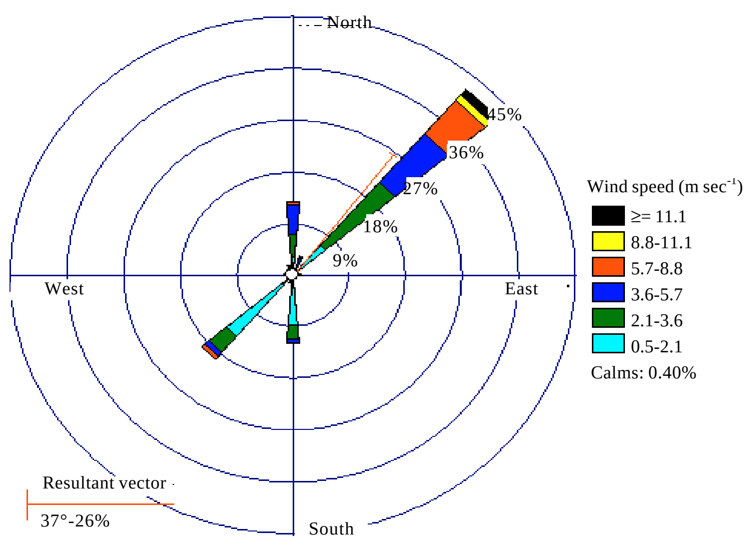

Fig. 1: Wind rose diagram of shahroud station

Table 1: Sectors inscribed circles of the studied area based on the land use

No. of sector	Land use	Top sector (degree)	End sector (degree)
1	Urban	45	135
2	Agricultural field	135	45

Table 2: Values of surfac parameters used

Season	No. of sector	Albedo coefficient	Bowen surface ratio	Surface roughness (m)
Spring	1	0.35	2.0	1.000
	2	0.60	2.0	0.001
Summer	1	0.14	2.0	1.000
	2	0.18	1.0	0.050
Autumn	1	0.16	4.0	1.000
	2	0.18	2.0	0.100
Winter	1	0.18	4.0	1.000
	2	0.20	2.0	0.010

meteorological files are prepared by AERMET. One file contains scalar surface and the other consists of vertical profiles of meteorological parameters. In order to apply the Terrain, the necessary information about the topography of the study area should be provided by AERMAP.

In this study, the meteorological data file was prepared for AERMET Preprocessor. Hence the parameters of rainfall, cloud cover, atmospheric and sea level pressure, the dew point temperature, wind direction, wind speed and moisture content are considered as profile parameters. To achieve the required meteorological data, the information recorded by Meteorological Organization Station of Shahroud was used. After the data file containing the weather parameters prepared, Bowen surface ratio, Albedo coefficient and surface roughness length based on the vegetation type and land use around the study area were determined. Then inscribed circles of the study area in a clockwise rotation were drawn and the values of these three parameters introduced in the Preprocessor Guide AERMET. Table 1 represents land uses of drawn inscribed circles and Table 2 shows the values of these three parameters on the surface for each season of the year.

AERMOD input: In this study, the spatial distribution modeling of particular matters emitted from cement factory chimneys were investigated for averages 1, 3, 8, 24 h and 1 month in 2012. Three receptors in the Cartesian coordinates, with the sizes ranging from 10×10 km^2 with grid spacing of 50 m, 20×20 km^2, 100 m and 40×40 km^2 and 200 m in both X and Y directions were defined. It is necessary to mention that the dispersion of pollutants released from the cement factory chimneys were simulated for three acceptors located at a height 1.5 m from ground level.

RESULTS AND DISCUSSION

Arc GIS was used to better shows the results obtained from AERMOD model. PM distribution for three areas of 10×10, 20×20 and 40×40 km^2 based on the average concentration for the time of study (2012) are shown in Fig. 2, 3 and 4, respectively. It is shown that the ambient concentrations beyond a distance of about 20 km from the cement plant are in compliance with the Standard. For distances less than 20 km near the vicinity of the plant, PM concentration is high and recommended mitigation measures should be implemented to control the emissions of dust

Table 3: Comparison of modeling results with standards

				Model output (1.5 m height)	
Pallutant	Standard	Year	TSP as standard (μg m^{-3})	Maximum concentration in the areas (μg m^{-3})	Comparison with standard (%)
PM10					
24 h	National (Iran)	2009	150	82.59	55
		2010	90		92
		2011	50		165
	EPA	2012	150		55
Annualy	National (Iran)	2009	150	30.50	20
		2010	40		76
		2012	20		153

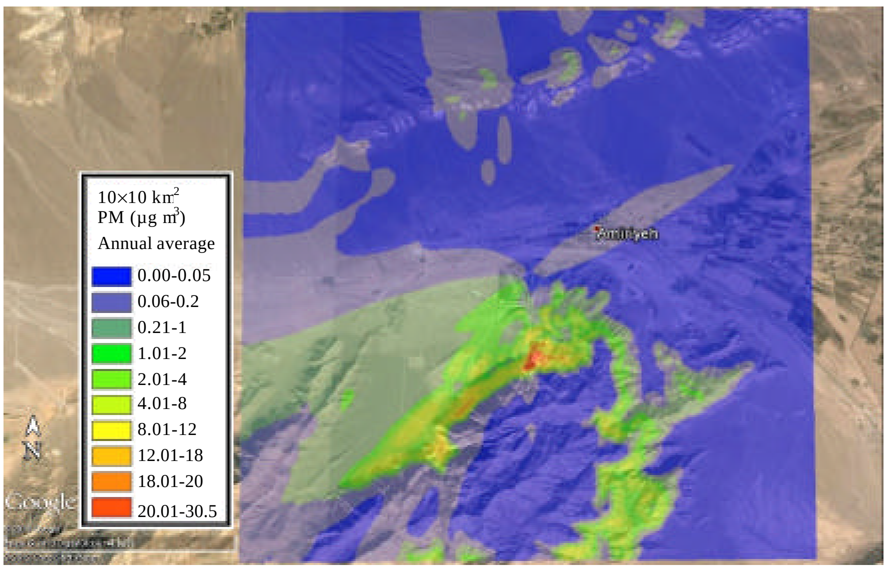

Fig. 2: Distribution of PM (μg m^{-3}) for the mean time of 12 months (2009) in the range of 10×10 km^2

components. Our findings are consistent with other researches in which PM concentrations exceeded the values set by the standard near the vicinity of the cement plant at a close distance (Al Smadi *et al.*, 2009; Tervahattu *et al.*, 2001). The results of the model output were compared with pollution standards. Table 3 compares the model output with the highest concentration with national standards. It is evident that PM concentration in the vicinity of the cement industry is higher. By looking at Fig. 2-4, it is evident that the highest annual dust concentration is experienced by points located to the South-West of the plants. This implies that North-East wind results in high dust concentration and it justifies the effect of prevalent wind which resulted in south-east PM accumulation. This observation has to be considered in deciding where to locate the emission controlling plants. As seen in the Table 3, the maximum concentration of 24 h and annual at a height of 1.5 m exceeded the standards of Iran national standards legislated in 2012 (165 and 153%, respectively). In other cases PM concentration is in compliance with the national and EPA standards. The largest emission source of dust is the kiln operation, which includes the feed system,

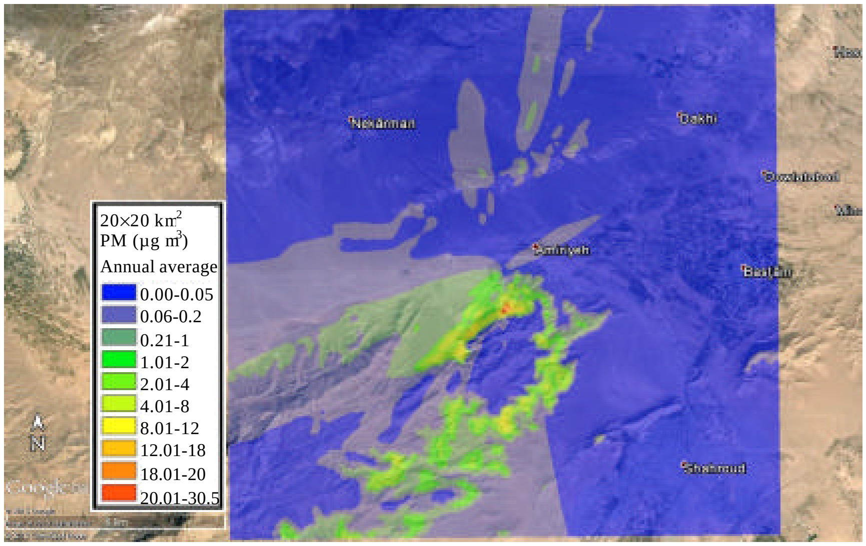

Fig. 3: Distribution of PM (µg m^{-3}) for the mean time of 12 months (2009) in the range of 20×20 km^2

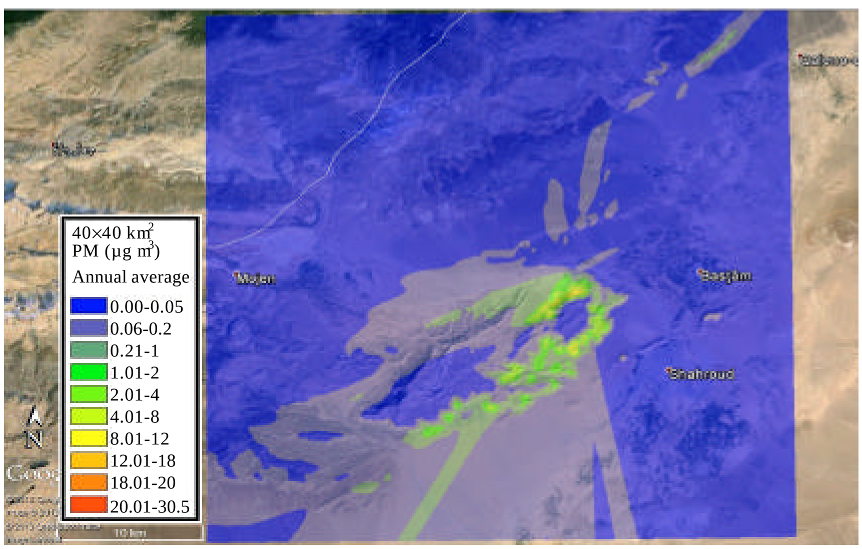

Fig. 4: Distribution of PM (µg m^{-3}) for the mean time of 12 months (2009) in the range of 40×40 km^2

the fuel firing system, the clinker burning, cooling and hauling systems (EEAA, 2005). Further researches are needed to evaluate the effects of other pollutants including CO, NO_x and SO_2 emit from Shahroud cement industry.

CONCLUSION

This study presents predictions of particulate matters emitted from a proposed cement factory constructed 15 km north of Shahroud city, Iran. AERMOD and local meteorological data were used to predict the PM concentrations in the vicinity of the plants order to ensure compliance with the National standards for ambient air quality reported in 2009-2012. Our findings indicated that concentrations of PM are found to be well below the permissible Standards for ambient air quality. Therefore, the proposed activity is not likely to have any significant adverse impact on the air environment in the vicinity of the proposed industryt. However, The TSP concentration is expected to be high at South-West of the industry plants where the prevail wind mostly blows.

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