Environmental Industry Letters
https://ijitis.org/index.php/EIL
ISSN:2806-2965
Volume1, Issue2
DOI: https://doi.org/10.15157/eil.2023.1.2.91-100
Received: 13.09.2023; Accepted: 28.10.2023

Modeling the Distribution of Suspended Particles in Sabzevar Lar Cement Factory with the AERMOD Model

Saiedeh Anavi[1*], Alireza Pourkhabbaz[1], Khosro Ashrafi[2]

[1] Department of Environmental, Faculty of Environmental and Natural Resources, University of Birjand, Birjand, Iran

[2] Department of Environmental Engineering, Faculty of Environment, University of Tehran, Tehran, Iran

***saiedeh.anavi@gmail.com**

Abstract

Today, air pollution is a significant issue, and one of the most significant environmental polluters is the industrial sector. In order to manage and impose limitations on sources of pollutants, monitoring air quality and assessing the amount of breaching air pollution limits around industrial enterprises is a valuable tool. Air pollution distribution models are thought to be the simplest and most practical way to monitor and evaluate the concentration of pollutants as well as to adopt suitable management techniques and strategies to reduce air pollution sources because it is currently not possible to directly measure the concentration of pollutants in any place and time. Therefore, the distribution of suspended particles (PM10) from stationary sources (chimneys of Lar Sabzevar Cement facilities) was examined annually for five years in each 24-hour period in this study using the AERMOD model. The highest number of suspended particles, which is substantially lower than the Iranian environmental limit of 150 g/m3, was found to be 3.36 g/m3. Results also indicated that the Lar Sabzevar cement mill does not produce significant environmental issues in terms of suspended materials, with an average yearly concentration of suspended matter owing to plant activities not exceeding 0.866 g/m3. Due to its location in the northeastern portion of the cement factory and its strong easterly breeze, Sabzevar is insulated from the impacts of cement factory operations.

Keywords: Air pollution; AERMOD model; Cement factory; Modeling; Suspended particles

INTRODUCTION

Today, environmental protection is one of the most important concerns in human societies. Through laboratory and experimental investigation, it is currently unable to pinpoint problems such as urban air pollution, acid rain, and the global effects of air pollution. Consequently, there is an increased necessity for simulating such processes in air pollution control management systems [7]. In the present, atmospheric scientists can apply their scenarios, create their hypotheses, and assess the accuracy of those hypotheses in a numerical laboratory setting called air pollution modeling [6]. Having expertise in areas like mathematics, physics, chemistry, meteorology, ecology, and management is necessary to solve the complex, multidimensional, and multifarious challenge of air pollution modeling [4]. In the modeling phase, a dynamic link between emission sources and concentrations is formed, providing the distribution of pollutants in areas without measuring stations at the end [9]. Due to topographic constraints and a lack of equipment, one of the issues that companies frequently have when estimating the quantity of pollutants is that it is not always possible to measure the amount of pollutants at great distances. In these situations, simulation software is used to calculate the amount of pollution in various places, and the simulation findings are compared with observations in nearby areas [5]. The American

Environmental Protection Agency first unveiled the AERMOD model in 2004 [7]. A distribution model with an eternal state is AERMOD.
The steady-state dispersion model AERMOD is used to estimate the surface and vertical emission of pollutants from point and volumetric sources, as well as various kinds of surface pollutant sources. It is used to estimate the concentration of various pollutants in urban and rural areas, as well as flat and uneven spots. Additionally, it is a reliable technique for simulating the dispersion of contaminants at a distance greater than 50 km from the emission source [5].

Numerous studies, such as those by [8] and [1], demonstrate the best efficiency of AERMOD in examining the dispersion of contaminants. Furthermore, maintaining human life requires adherence to environmental standards [10]. The cement business is one of the biggest, most significant, and most significant sources of air pollution in the world [7]. Iran's cement industry dates back more than 75 years. Due to its significant economic impact, it has played a unique role in national industry and is currently regarded as one of the key industries in the process of industrial growth. The environment is impacted by industry. Consequently, it is vital to provide practical solutions by locating, measuring, and keeping an eye on the sources of pollution in order to comply with environmental standards [3]. As one of the biggest cement producers in Iran, Lar Sabzevar Cement Factory was therefore considered a source of pollution emissions in the current study. The Parvand Protected Area, Sabzevar City, and Parvand Village are the primary recipients of pollution in the area surrounding the Sabzevar cement mill because they are nearby and are immediately impacted by its pollutants. The majority of pollution in cement plants is caused by suspended particles, and the primary sources of pollution and emission of these particles are cement kilns, their fuel consumption, cement mills, and other machinery such as transmission and feeding systems and silos [3]. The phrase "particulate matter" (PM) refers to solid and liquid particles that are less than 500 m and larger than individual molecules, which have a diameter of around 0.0002 m. This size of particle has a suspended shelf life of a few seconds to a few months. Due to collisions with individual molecules, random Brownian movements have an impact on particles smaller than 0.1 m in diameter. In still air, particles with a diameter between 0.1 m and 2 m exhibit sedimentation velocities; however, these velocities pale in comparison to wind velocities. These particles often get washed away by rain when it forms. Studies on the pollution of suspended particles from industry, especially cement manufacturers, have been undertaken over the past few years, including [11]. The AERMOD dispersion model is effective in identifying regions with significant pollution effects, according to the results. In the current study, the manner and quantity of suspended particle emission in the Sabzevar cement factory, as well as the factors affecting the emission of these particles, were discussed using the AERMOD model, taking into account previous studies and the significance of examining the pollution rate of the fundamental industries.

MATERIALS AND METHODS

a) Study area

The Sabzevar cement factory is situated 75 kilometers south-southwest of Sabzevar city, in the Rudab area, in longitudes 494245 to 508734 east and latitudes 3953407 to 3976071 north (UTM coordinate system). Located within the Parvand Protected Area is the factory. The factory occupies around 150 hectares and produces 3,700 tons of cement per day. The annual fuel consumption is 81 million cubic meters of natural gas. The raw material, clay, is mined from Mir Ali Hill, which is five kilometers from the facility. Other raw materials, such as gypsum and iron, are supplied by gypsum mines in the counties of Shashtmad and Bardaskan, respectively. The predominant climate in the region of Parvand is a cold desert. The predominant wind direction is from east to west, with an annual average velocity of 3.84 meters per second.

b) Fauna and flora of the study area

The Parvand Protected Area contains an abundance of animal species. Rams, ewes, goats, deer, wolves, foxes, caracals, jackals, porcupines, rabbits, and rodents such as Allactaga elater are notable mammals in the region. Birds of this area include Golden Eagle, Long-legged Sargape, Saker falcon, Kestrel, Small Owl, Partridge, See-see Partridge, Bustard, Pterocles, Sandgrouse, Blue Rock Thrush, Desert lark, Crested lark, Streaked scrub warbler, Great Grey Shrike, Desert finch, Trumpeter finch, European bee-eater, Isabelline wheatear, Variable wheatear, Clay-colored sparrow, and Iranian ground jay. In the Parvand region, reptiles include the gray toad agama, Pseudocerastes, Phrynocephalus, Schokari sand racer, black ocellated racerunner, Platyceps rhodora chis, Persian racerunner, Spotted Desert Racer, Caspian bent-toed gecko, Spalerosophis diadema schiraziana, desert monitor, and baluch rock gecko [2].

The arid and desert climate adjacent to the desert plain has a significant impact on the vegetation communities of the region's vegetation cover. In addition to meeting the biological needs of numerous wildlife species, the region's plants are drought-tolerant and adapted to harsh environmental conditions; they also play an important role in stabilizing the soil and preventing erosion. In addition to annual plants, important species in this region include Atraphaxis, Calligonum, Pistacia atlantica, Artemisia, Zygophyllum, Amycdalus Lycioides Spech, Tamarisk, Astragalus, Atriplex, and Yarrow. It is notable that only one ancient juniper tree survives in the region's eastern mountains.

c) Meteorological observations

Meteorological data were utilized to model the distribution of pollutants from the Sabzevar cement factory's various sources. From the Iranian Meteorological Organization, meteorological data for the past five years (2013–2018) were obtained. The data was utilized after AERMET and AERMOD software had refined it. The obtained meteorological data included the date, wind speed, wind direction, cloudiness, temperature, humidity, and pressure, among other variables.

d) Topography of the study area

Due to the fact that cement factories are always constructed in the vicinity of limestone mountains in order to provide cost-effective materials and reduce transportation costs, topography must be accounted for in order to create an accurate model. The Iranian National Cartographic Center compiled topographic data for a 70-kilometer radius around the Sabzevar cement factory for this purpose.

e) Emission values from Sabzevar cement sources

There are five primary sources of particulate and gas pollution at the Sabzevar cement factory, as determined by site visits and employer-provided information. The data are presented in Table 1.

Table 1. Information on sources of pollution in Sabzevar cement factory

Source Parameters	Great cooler	Mill output 2	Furnace	Six silos	Mill output 1
Diameter (m)	1.9	1.9	3.5	0.45	1.9
Exhaust gas temperature (C)	119	80	155	14	33
Gas velocity (m/s)	15	16.5	13.5	17.5	15
Flow rate (m^3/s)	42.57	46.83	130.02	2.78	42.57
Average particle concentration (mg/nm^3)	0	52.95	108.83	90.92	57.7
Average concentration of SOX (mg/nm^3)	0	0	3.53	0	0
Average concentration of CO (mg/nm^3)	16.25	0	53.37	0	0
Average concentration of NOX (mg/nm^3)	71.86	0	100	0	0

f) Modeling the scattering and dispersion of suspended particles using AERMOD

AERMOD is a permanent state scattering model used for determining the concentration of various pollutants in urban and suburban areas, smooth and uneven regions, surface emissions, and at high altitudes for determining point and massive sources in addition to various types of surface sources. The model is highly recommended for simulating the dispersion of pollutants up to 50 kilometers away from their sources. Two preprocessors are utilized by the AERMOD model to simulate the distribution of pollutants. a) A preprocessor for AERMET that processes meteorological data and estimates atmospheric boundary layer characteristics b) The AERMAP preprocessor that prepares the study area's topographic data AERMOD has been designed to simulate particle and gas dispersion. In this model, the atmosphere is described by a series of similarity scaling relationships that utilize measurements of surface wind speed, wind direction, and temperature to predict vertical profiles of wind speed and direction, temperature, turbulence, and temperature gradient. This model includes both dry and wet gas deposition.

g) Modeling, emission sources and capabilities

The EPA recommends this Gaussian model, which is comprised of four modules:

1: AERMET as a module for meteorology 2: BPIP as a construction module. 3: AERMAP as a module for topography 4: AERMOD as a module for calculating concentration and output.

This software's meteorological module, AERMET, is responsible for converting raw meteorological data into the meteorological parameters and boundary layers required by AERMOD. AERMET processes the raw meteorological data in three steps: data reading and quality control, data merging, boundary layer parameter calculations, and the generation of two outputs for AERMOD.

AERMAP is responsible for implementing topography and land features on sources, receivers, and network nodes. In the building module (BPIP), the effect of downwash pollutant subsidence is investigated and applied due to the presence of buildings. This module simulates the effects of a building by determining the extent and range of the building's impact on the source and converting the actual building's length, width, and height to equivalent values. The capabilities of AERMOD View 8.9 are described as follows:

Simulation of pollutant release from fixed industrial sources up to distances of about 50 kilometers, release from surface sources, near the surface, elevated sources, with urban or rural location, with continuous plume type and floating plumes, investigating the effects of buildings by PRIME algorithms, receiving meteorological data from multiple altitude levels, assessing the risk of exposure according to American standards, considering the effects of the subsidence of pollutants caused by the existence of buildings, modeling geographic effects, modeling various sources of pollution and odors, chemical modeling of the transformation of nitrogen oxides in three ways, modeling of gas and particle sedimentation during plume movement, modeling of particle removal during plume movement, output matching with Google Earth and ARCGIS maps, drawing different types of concentration contours as defined by the user and determining the types of concentration maxima at each point, converting different meteorological data into appropriate model inputs.

RESULTS

a) Results of the meteorological observations

The results of the region's meteorological data are depicted in Figure 1, a wind rose derived from the 5-year meteorological data of Sabzevar city. Despite the heights in the north and south of Sabzevar city and the openness of the east and west sides of this city, a suitable wind corridor has been created, which leads to the wind blowing in the east-western direction, as shown in figure 2.

In addition to the data obtained from the wind rose, different wind speed classes are depicted in figure 1. 13.5 percent of the total winds in Sabzevar are calm, and winds with a speed between 3.6 and 5.7 meters per second occur the most frequently, accounting for 30.4% of all winds. It should be noted that calm winds are not included in the modeling of diffusion and dispersion because they are too calm and stationary.

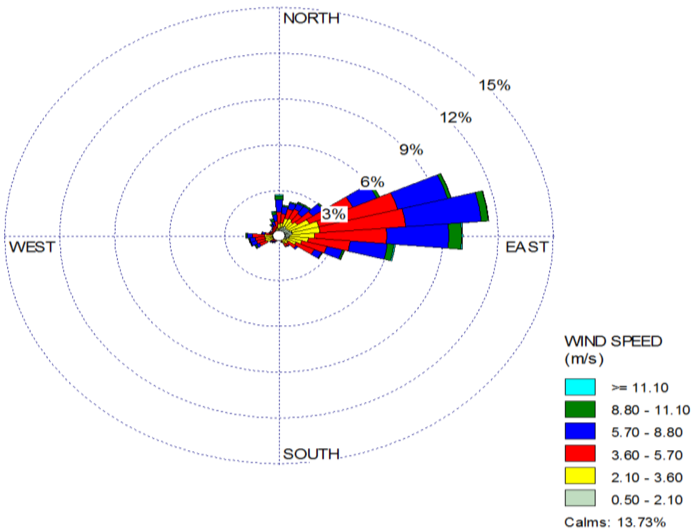

Figure 1. wind rose diagram of the last 5 years of Sabzevar city

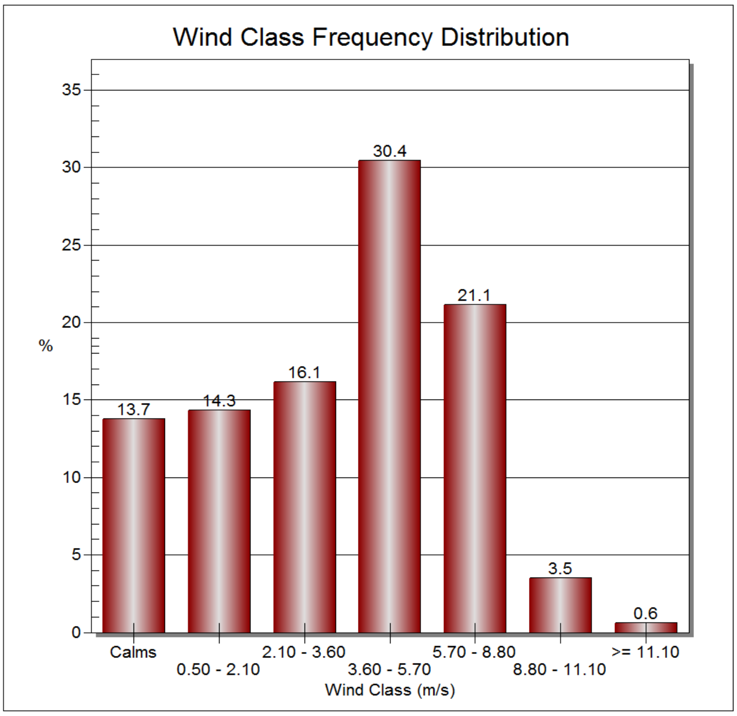

Figure 2. Distribution analysis of wind speed and direction classes for the last 5 years in Sabzevar

b) Modeling the topography of the region

Figures 3 and 4 depict the location and unevenness of the Sabzevar cement factory. As stated in the previous section, the presence of an east-west corridor causes wind to blow in the same direction in Sabzevar city, as shown in figures 2 and 3. The presence of heights to the north and south of Sabzevar prevents north-south winds from blowing.

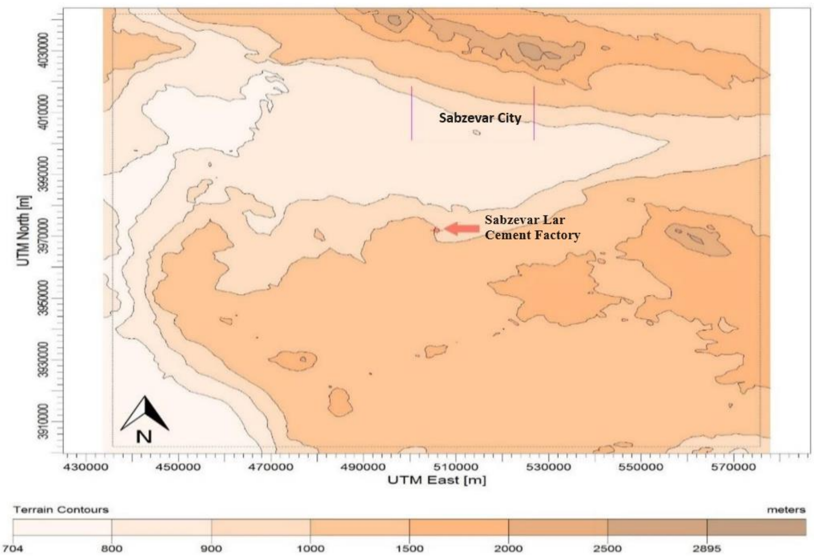

Figure 3. Topographic situation up to a radius of 70 km from Sabzevar cement factory

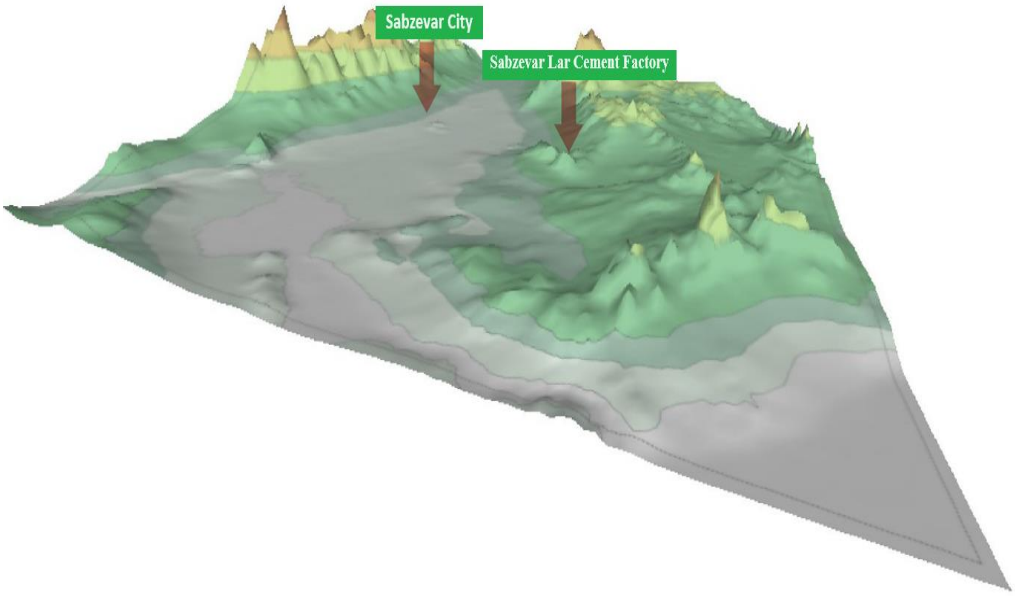

Figure 4. Another view of the three-dimensional topography up to a radius of 70 km from Sabzevar cement factory

c) Modeling Sabzevar cement factory

The corrected values were determined by a reputable laboratory, as were the flow output values. Moreover, the emission of pollutants from various sources is computed. The emission values of various pollutants are displayed in grams per second in Table 2.

Table 2. Values of emission coefficients from Sabzevar cement factory pollution sources

Emission amount (g/s)	Sources				
	Mill output 1	**Six silos**	**Furnace**	**Mill output 2**	**Great cooler**
Particles	2.45	0.253	14.15	2.47	0
SO_X	0	0	0.45	0	0
CO	0	0	6.93	0	0.69
NO_X	0	0	13.00	0	3.05

Sources such as mills 1 and 2 and silos emit only particulate matter and no gaseous pollutants. It should be noted that, depending on the type of process and product, the primary pollutant in cement factories is a variety of particle types.

d) AERMOD dispersion modeling results

The Sabzevar cement complex can be modeled based on the characteristics of pollution sources in the factory as well as meteorological and topographical data. To this end, the AERMOD model was used to model Sabzevar cement particles for a period of 5 years. The summary of the data entered into the AERMOD model is presented in Table 3.

Table 3. Specifications of the modeling method

Parameters	Entered value
Modeling components	The desert area around Sabzevar
Surface meteorological data	Measured hourly from 2013 to 2018
Included Meteorological parameters	Wind speed, wind direction, cloudiness, temperature, pressure, humidity
Land use	Desert land use, with albedo coefficients of 0.32 and 4.62, roughness of 0.26 meters
Modeling type	Rural
Pollutant	Suspended particles, 24-hour output
Sources	Output of mill 1and 2, furnace and silo with a height of 50 meters
Modeling radius	50 km, regular network with 441 points
Topography	Topography is included with a resolution of 90 meters

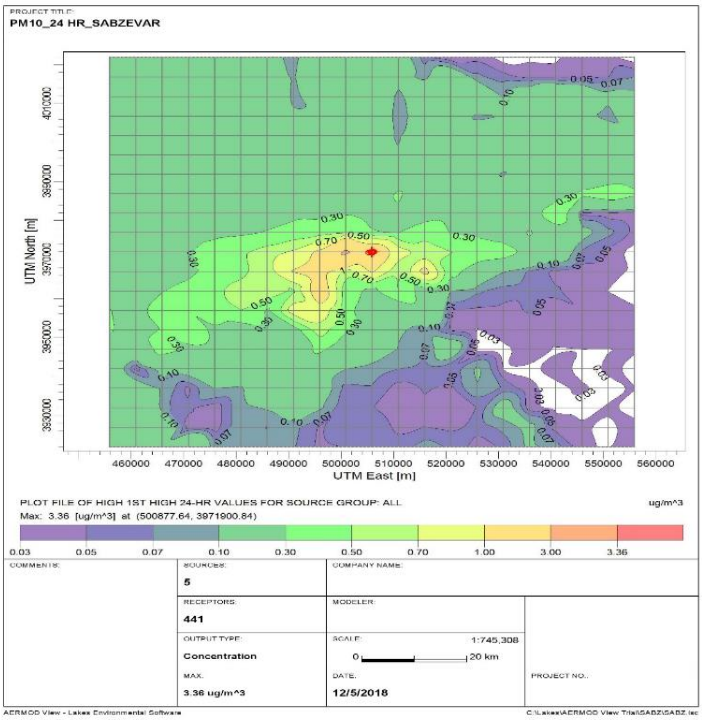

Figure 5. Maximum 1-hour concentration of PM10s emitted from the sources of Sabzevar cement factory in 5 years.

As can be seen, the maximum 24-hour concentration of particles during these five years was 3.36 micrograms per cubic meter, which is a very small number compared to the Iranian environmental organization's 24-hour standard (150 micrograms per cubic meter).

Figure 5 depicts the 5-year mean concentration of PM10 particles. Evidently, the concentrations correspond well with the Sabzevar wind rose diagram, and the annual average concentration of particles resulting from factory operations does not exceed 0.866 micrograms per cubic meter.

DISCUSSION

To accurately examine the effects of pollutants, it is necessary to examine and model all gaseous pollutants originating from factory chimneys. To reduce the number of pollutants in the cement factory, it is recommended to employ effective measures. The number of environmental pollutants should be measured and compared to the concentration of pollutants predicted by models. Before constructing industries and factories, the release of pollutants from these industries should be modeled to determine the impact of pollutants on the surrounding area and to prevent the production and release of pollutants into residential areas. Continuous monitoring of the region's air quality is required to effectively manage the critical conditions. On the other hand, it is necessary to investigate the impact of these pollutants on the soil and water quality of the region under study.

CONCLUSION

Using AERMOD, this study investigated the modeling of suspended particles at the Lar Sabzevar cement factory over annual periods. In general, the results indicated that the maximum amount of particles in the factory's output in a 24-hour period during these five years was 3.36 micrograms per cubic meter, which is a very small amount compared to the Iranian environmental organization's 24-hour standard (150 micrograms per cubic meter). In addition, the average annual concentration of particles resulting from factory operations is 0.88 micrograms per cubic meter. Consequently, the Sabzevar cement factory does not contribute to particulate matter pollution. Considering that Sabzevar is located on the northeastern side of the factory, it is unaffected by the factory's activity. On the other hand, due to the prevalent wind and weather conditions, the factory's pollution does not move towards the city and Parvand's protected area.

CONFLICT OF INTERESTS

The authors confirm that there is no conflict of interest associated with this publication.

REFERENCES

[1]. Ashrafi, Kh., 2013. Modeling the distribution of particulate pollutants from North Cement Company. Research project, Faculty of Environment, University of Tehran (in Persian).

[2]. Jafari Benqani, S., 2018. Environmental effects of Lar Sabzevar Cement Factory, Faculty of Basic Sciences, Tarbiat Moallem Sabzevar University (in Persian).

[3]. Rahman, H., 2014. Monitoring and modeling of suspended particles from Abek cement factory and evaluating the risk of polluting suspended particles on people's health in surrounding cities. Master's thesis. University of Tehran (in Persian).

[4]. Abbasi, M., 2014. Modeling the distribution of suspended particles of Saroj Cement Factory and its effects on the accumulation of heavy metals in soil and plants. Thesis of Master's degree in Natural Resources Engineering, Environmental Pollution, Faculty of Natural Resources, Isfahan University of Technology (in Persian).

[5]. Atabi, F., Abbaspour, M., Karbasi, A., Haji Seyed Mirzahosseini, A., 2016. Modeling of suspended particle emission using the ADMS Urban model. Environmental Science and Technology. Third year.9(1): 1 -15. (in Persian).

[6]. Amid M., 2008. Modeling the emission of production pollutants in Bo Ali Sina Petrochemical Complex, Master's Thesis. Faculty of Environment, University of Tehran (in Persian).

[7]. Kazemi Shahrabi, N., Nurpour, A., 2013. Investigating the amount of TSP pollutants emitted from industrial chimneys by pollution distribution modeling. The first international conference of cement industry, energy and environment (in Persian).

[8]. Mohan, M., Bhati, S., and Rao, A., 2011. Application of air dispersion modelling for exposure assessment from particulate matter pollution in mega city Delhi. Asia-Pacific Journal of Chemical Engineering. 6(1). 85-94.

[9]. Crowl, D.A., and Louvar, J.F., 2001. Chemical process safety: fundamentals with applications. Pearson Education.US.

[10]. Baroutian, S., Mohebbi, A., and Soltani Goharrzi, A., 2006. Measuring and modeling particulate Dispersion: A case study of Kerman Cement Plant. Journal of Hazardous Materials. 136: 468-474.

[11]. Seangkiatiyuth, K., Surapipith, V., Tantrakarnapa, K., and Lothongkum, A. W. 2011. Application of the AERMOD modeling system for environmental impact assessment of NO2 emissions from a cement complex. *Journal of Environmental Sciences*. *23*(6): 931-940.