ASSESSMENT OF POLLUTION LEVEL FROM CEMENT PLANT USING BREEZE AERMOD DISPERSION MODELING (CASE STUDY APPLIED ON HELWAN INDUSTRIAL AREA)

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ABSTRACT

Coal is an essential component of the energy production; it was necessary to review the environmental standards and requirements to include all activities related to the use of coal or petroleum coke. Cement plants considers the largest stations producing pollutants known globally as very dangerous emissions as (CO, PM10, SOx, NOx).

Especially in the area Helwan, in which a group of different industries are concentrated. So that, it was necessary to assess environmental pollution loads. The main objective of this study is to use mathematical models (Breeze AERMOD) Dispersion Modeling software to assess the environmental level resulting from using the coal as alternative fuel instead of natural gas and assess the environmental impact for this transformation. By studying the general location of Helwan area and identifying sensitive receptors and identify the level of pollution generated cement industry.

Keywords: AERMOD; Cement industry; Emissions, Helwan Pollution, Dispersion Modelling

INTRODUCTION

The cement industry has increased in Egypt; due to the availability of raw materials used in the industry in different places. All of the cement plants replaced coal instead of natural gas to be use as a fuel in the kilns to produce the clinker – an intermediate product, which grinded with other raw materials to produce cement in its final form. It is known that the use of natural gas as a fuel is one of the energy sources with a low impact on the environment, compared to the other energy sources such as coal [1]. In recent years, many countries, including Egypt, have faced difficulties in providing energy sources, such as natural gas which cause intensive increase in all prices. Most of cement plants tried to use other sources as fuel at lower prices, such as coal. This transformation made a noticeable change in the rates of emission of pollutants into the environment. Therefore, it was necessary to study the level of increase in pollutants concentrations on the surrounding communities near the cement plants. The cement industry is one of the important industries that responsible for air pollution; as the resulting pollutants are a major cause of respiratory diseases for people that may expose to it [2]. Recent studies on the emission rates of various pollutants from cement plants indicate that they have increased in the last three decades at very high rates, they increased rapidly 1 to 21 times [3]. Therefore, it is necessary to study the pollution load which has direct impact on health of the communities living near the cement plants especially that use coal as a fuel. Pollutants result from burning operations in cement plants that may have a harmful effect on the health of the communities that may live close to the plants. This study aims to predict the dispersion of pollutants with the surrounding area of Helwan cement plant within 20 Km around the facility, the pollutants included in this study are PM10, CO, NOx and SOx. This type of modeling studies the dispersal of pollutants from the studied cement plant, which will entail the necessary measures to be taken if the results do not conform with health requirements and environmental regulations. To carry out the assessment, four pollutants resulting from the emissions of the stack of the cement plant were selected: particulates matters with 10 micron PM10, carbon monoxide CO, sulfur oxides Sox and nitrogen oxides NOx that have direct impact on environment and health of the surrounding area, especially with high rate of flow. There are many methods to implement pollution load assessment for the emissions from cement plants. However, in this study, the Breeze AERMOD modeling program will be used to obtain the results of giving a prediction of the concentration of the pollutants in the surrounding environment of the cement plant.

The objectives the study are to:

- Identify the level of pollutants concentrations that resulting from cement factory
- Present how the emissions diffuse and disperse over the surrounding area
- Compare the results with applicable regulations for ambient air quality

STUDY AREA

The studied cement plant is located on the Helwan Nile Corniche, south of the main entrance to Helwan City, 30 km south of Cairo, in the eastern part of the sedimentary plain of the Nile Valley in Cairo Governorate; At the intersection of longitude 31°18'36.30" east and latitude 29°49'19.62" north, about two kilometers from Farouk's corner at the entrance. The factory is bounded from the north by the spinning and weaving factory, and from the east by a vacant land belonging to the Helwan Airport of the Arab Authority For manufacturing, and from the west the Kafr El-Elo water station and some small estates and residential buildings on the Nile Corniche, and from the south, the population centers of Arab El-Barawi and Arab Kafr El-Elou. Figure1 shows the location of the factory and the urban distribution around it. The site includes two production line that contains the following areas: limestone crusher, additives, limestone storage, raw mill, preheater, by pass, kiln, cooler, gypsum crusher, coal mill, cement mill, cement silos and packing areas. The emissions measurement results used in the study are the average periodic measurement from the stack of the studied cement plant during 2021. The data collected from Air Quality Management Department in Egyptian Ministry of Environmental Affairs through the continuous emissions monitoring system CEMS which monitor all of heavy industries emissions. Measurements of the emissions from the stacks of studied cement plant were implemented to find out the results of pollutants emission and their compliance with the permissible ratios in the Egyptian Environmental Law 4/1994 (and its amendments by Law 9/2009) [4].

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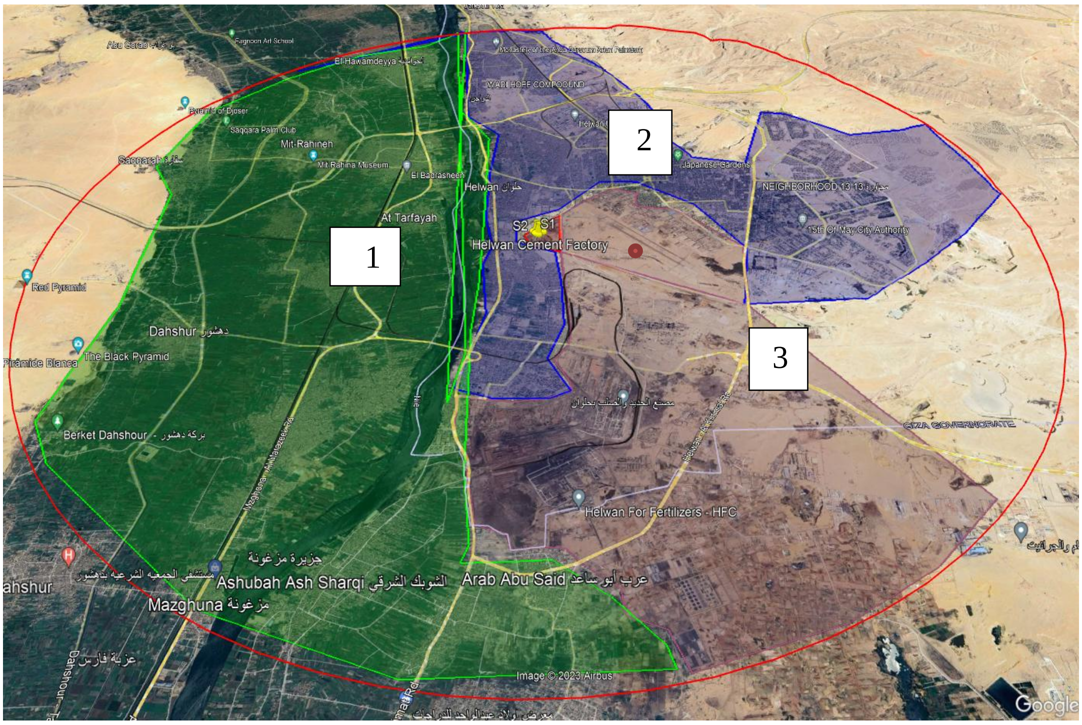

Figure 1: Uses of surrounding area for the cement plant, 1: Mix of Agriculture and Residential Areas, 2: Mainly residential and commercial areas, 3: Industrial area

MATERIAL AND METHODS

Data Collection: Many data required for dispersion modelling software to run the simulation process including the basic data for the stacks parameters (flow of emissions, flow velocity, stack height, stack diameter, and stack temperature), in addition, full meteorological data for the study area which divided to two files (Source, profile) contain many parameters.

Surface file: The surface meteorological data file consists of a header record containing information on the meteorological station locations, and one record for each hour of data over full year, i.e., Sensible heat flux , Surface friction velocity, Vertical potential temperature gradient in the 500 m layer above the planetary boundary layer, Height of the mechanically-generated boundary layer,…etc.

Profile file: a profile meteorological data file for use in the model run. The profile meteorological data file consists of one or more records for each hour of data over

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full year. As with the surface data file. The profile meteorological data file contains a lot of data such as: Measurement height, Wind speed for the current level, Temperature at the current level, etc.

The basic data for cement plant (stacks data) had been collected from Air Quality Management Department in Egyptian Ministry of Environmental Affairs through the continuous emissions monitoring system CEMS which monitor all of heavy industries emissions. The meteorological data (surface and profile files) purchased from certified company in dispersion modelling simulation.

Selected Model:

The BREEZE AERMOD is used as a Gaussian model for advanced dispersion modeling supported by the United States Environmental Protection Agency (USEPA). It is one of the most widely used models in the world. This model used to assess concentrations of pollutants from a comprehensive range of sources existing at any industrial complex. The model takes into account dry and wet conditions and includes mechanisms to determine the impact of soil, soil terrain and buildings on dispersion of gaseous emissions. The model uses a meteorological file using USEPA Model, which shows at each hour the wind speed, wind direction, and other dispersion factors. The model has the capacity to absorb those emissions that change together for time, or change due to weather conditions. Environmental impact factors for emissions from stacks calculated using a special program of the US Environmental Protection Agency (USEPA) [5]. The model can be applied to rural and urban areas, flat and complex terrain, surface and high emissions, multiple sources (including point sources, spatial sources, and volumetric sources). This model is based on the dispersion of emissions in the steady state. The model consists of the following components:

- Meteorology: Meteorological data and surface characteristics (e.g., mixing heights, velocity, friction, etc.) are used.

Maps: Teradata are used to estimate the level of terrain impact for each receiver, which calculates the concentration of pollutants including:

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- Dispersion of thermal transfer layers and stable layers.
- High contaminants and their buoyancy.
- The penetration of pollutants in reflective conditions.
- Determination of wind, disturbance and heat characteristics.
- The form of contaminants on all surfaces and at a height higher than the high dispersion of contaminants.
- Final processing: producing maps and tables for the resulting concentrations.

Then add these outputs from the model to the GIS system to extract digital maps paint the relationship between these emissions and the affected areas and thus to know the extent of the geographical spread of these emissions.

In the environmental studies, the environmental assessment is carried out either by field measurements from the surrounding environment by taking periodic samples over a specified period, or by following the hypothetical estimation system using some mathematical equations with the help of advanced systems such as the AERMOD program. AERMOD software using the basic data entered with other requirements such as meteorological data and land topography. The advantages of using modelling software are as follows: reducing the time required to complete studies and the cost of work and effort for people, predict the level of pollution for project under investigation and help us to evaluate the industrial and pollution control equipment. The program came out in 2004 by US- EPA, as a program used to simulate the dispersal of pollutants rates [6]. AERMOD is a program which has the ability to simulate extent of the concentration of pollutants from the source of emission in the surrounding areas and facilitates the study of environmental impact on the population near the source of pollution within certain distance, the steps to run the Breeze AERMOD program are shown in Figure 2.

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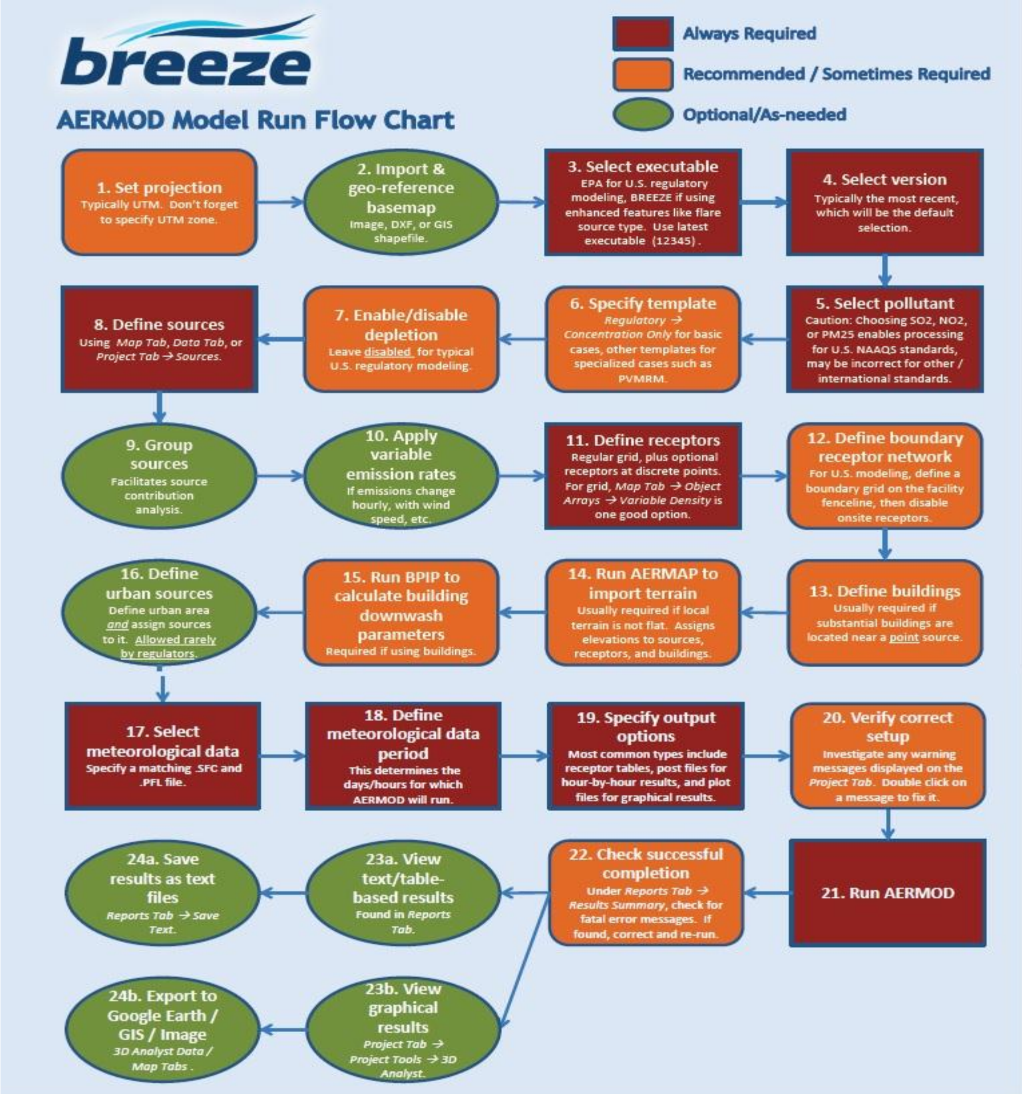

Figure 2: BREEZE AERMOD Flow Chart, Source (BREEZE AERMOD Manual)

Methodology and Approach:

Air pollutant modeling consists of:

- Selection of modeling locations of the pollution sources (the 2 stacks positioned at cement plant).
- Selection of pollutants to be modeled: Based on nature of the exhaust gases emitted from each stack as a result of coal combustion

- Selection of exposure environment: The model assumes that the ambient outdoor concentration is based on the used fuel combustion, which results in sulfur oxides (SOx), nitrogen oxides (NOx), mono carbon oxide (CO), and particulate matters (PM10). Limited impact on indoor air pollution

A normal scheme designed for the evaluation of the Air Quality Monitoring Network (AQMN); the study area divided into a continuous grid system in which each grid represent a candidate location for network stations. Hence, an optimization analysis, using statistical and mathematical programming models as screening tools, is to pick up the most appropriate subset in the grid system in the sense that design objective can be optimized with respect to cost, effectiveness, and efficiency criteria. A grid in the following formulation is thus equivalent to a candidate site waiting for possible selection in the trade-off process.

First, the cement plant was divided to a grid of small areas; then, the source of emission inside the power plant were specified. A software package was used to get hourly simulated air quality in each grid to obtain each pollutant concentration, and then, to determine the average daily concentration inside each grid location. After these steps, the location of the highest concentration of each pollutant in each grid and the frequency of violation were identified; the Figure shown below explains this procedure.[7]

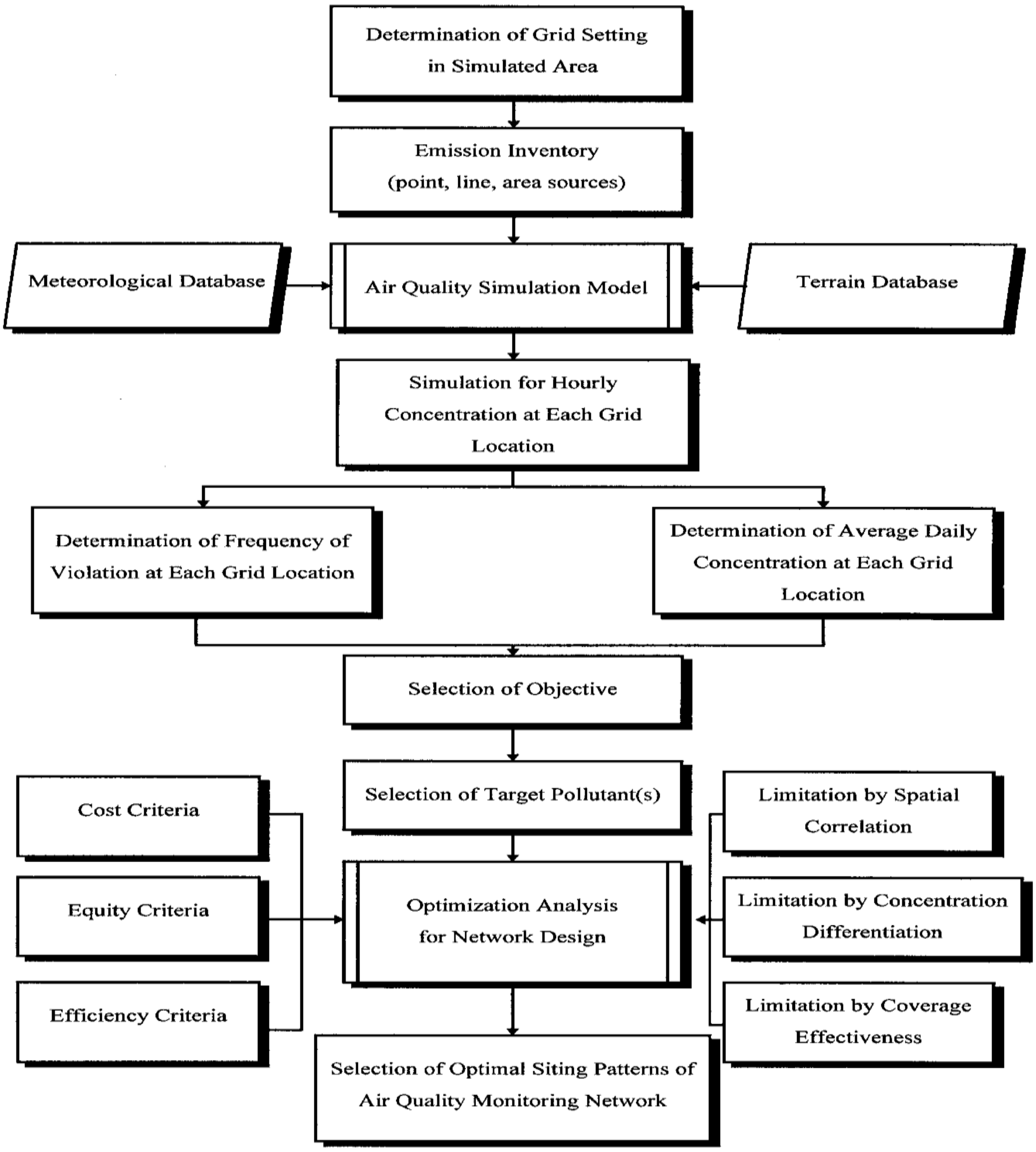

Figure 3: Procedure of Selection of Optimal Pattern of AQMN

Grid Sitting:

The cement plant and surrounding area was divided into 10000 cells to cover around 13 acres each; the receptors network gridded with uniform Cartesian grid at delta x = 250 m delta y = 220-meter run, each measured point will represent area around 55000 m2 (13 acres). The following Figure shows the details

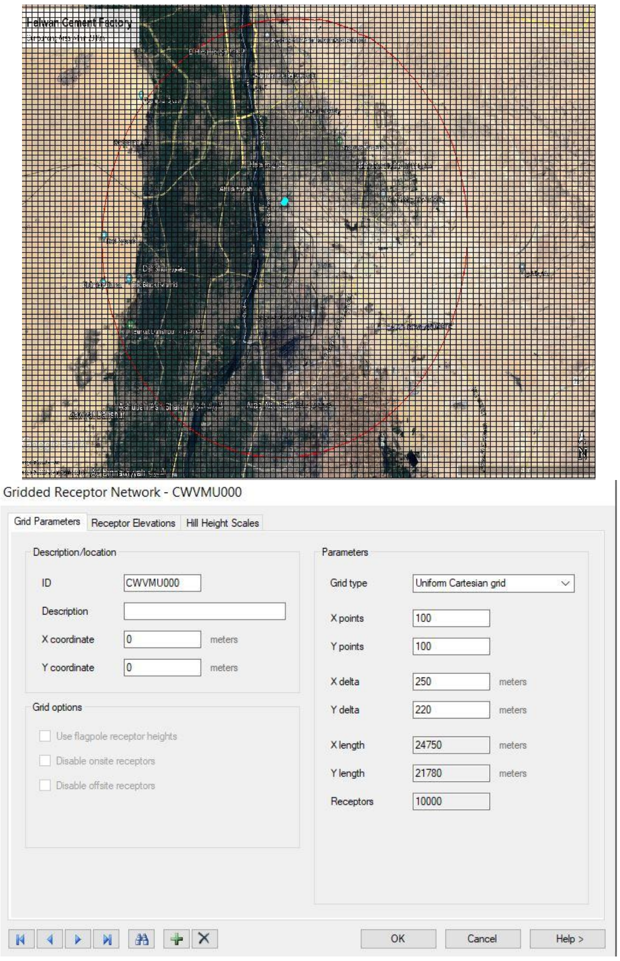

Figure 4: Grid receptor setting in breeze AERMOD software

Dispersion modeling Input Data:

The Breeze AERMOD is used to simulate pollutant dispersion inside power plant. The outcome of the model is the hourly concentration at each grid location; fifty (50) iteration trials were performed to attain the highest 50 concentration values in each grid. The average daily concentration at each grid location was then determined; this was repeated for several days.

The full range of the expected pollutants from all stacks was targeted including: CO, NOx, SOx, and PM10 to identify the level of pollutants concentrations and there dispersion within the surrounding area.

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A series of input data for each stack was fed to the model including coordinates, elevation, emission rates, stack height, flow temperature & velocity and stack diameter. The following Tables show the input data for each pollutant air modelling simulation.

Table 1: Dispersion Modelling Inputs Data for Breeze AERMOD Software.

SOURCE	X COORDINATE (M)	Y COORDINATE (M)	ELEVATION (M)	EMISSION RATE (GM/SEC)	STACK HEIGHT (M)	STACK TEMP. (^{O}K)	STACK VELOCITY (M/SEC)	STACK DIAMETER (M)
Input data in CO air modeling simulation								
Stack 1	11407.8	11890	25	207.13022	72	345	13.5	3
Stack 2	11368.2	11820	25	248.5562	40	488	9.45	21
Input data NOx air modeling simulation								
Stack 1	11407.8	11890	25	145.2905	72	345	13.5	3
Stack 2	11368.2	11820	25	174.3486	40	488	9.45	21
Input data SOx air modeling simulation								
Stack 1	11407.8	11890	25	207.1302	72	345	13.5	3
Stack 2	11368.2	11820	25	248.5562	40	488	9.45	21
Input data PM10 air modeling simulation								
Stack 1	11407.8	11890	25	785.0278	72	345	13.5	3
Stack 2	11368.2	11820	25	942.0334	40	488	9.45	21

The cement plant has two stacks treated as point sources of emission; the following Figure shows the cement plant; it indicates the location of the emission sources within the plant. Details The 2 stacks are attached to the cement kiln, which are fired by coal, stacks has diameter of 13.5 m and 9.45 m respectively and the height of them are 72 m and 40 m.

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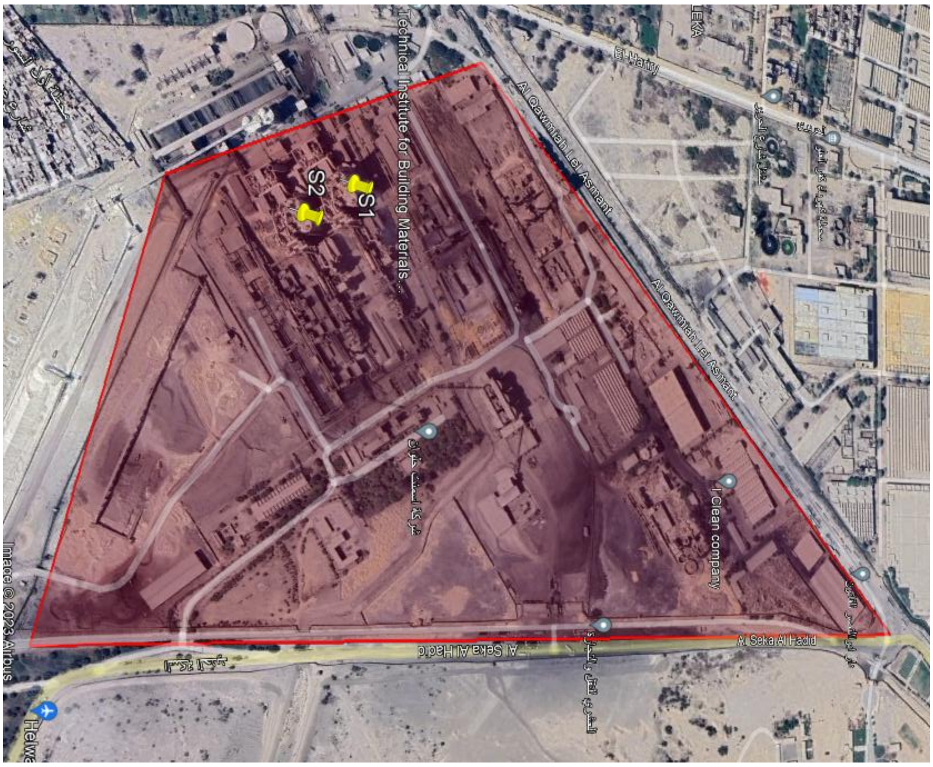

Figure 5: Stacks locations

RESULTS AND DISCUSSION

The modelling covered the dispersion of all pollutants over an hourly range emphasizing the maximum concentration as compared to the limits set forth by the law in the ambient. No limits exceeding was reported (full report is attached). The following section shall display the dispersion results of all pollutants in 1 hr, 8 hrs, 24 hrs and annual (as compared to the limits set forth by the law). The results presented in Table 2 with 5 statistics values for each measured period including:

- Max.: the maximum concentration found within the grid receptor points
- Min.: the minmum concentration found within the grid receptor points
- Mean: the average concentration found within the grid receptor points
- Median: the value in the middle of a data set
- Mode: refers to a number in a set of numbers that appears the most often
- Std. Dev.: measure of how dispersed the data is in relation to the mean. Low standard deviation means data are clustered around the mean, and high

standard deviation indicates data are more spread out

Table 2: Dispersion Modelling Results Using Breeze AERMOD Software.

POLLUTANT	AVERAGE PERIOD	EGYPTIAN DECREE NO 710/2012 (MG/M3)	MODELLING RESULTS (MG/M3)					
			Max.	Min.	Mean	Median	Mode	Std. Dev.
PM10	1 hr	-	5012	155	1334	1146	1372	726
	8 hrs	-	2357	61	499	394	345	355
	24 hrs	150	1490	21	230	182	367	168
	Annual	70	36	0	6	4	13	5
CO	1 hr	30000	1322	41	352	302	292	192
	8 hrs	10000	622	16	132	104	91	94
	24 hrs	-	393	6	61	48	97	44
	Annual	-	9	0	1	1	0	1
NOx	1 hr	180	928	29	247	212	205	134
	8 hrs	-	436	11	92	73	64	66
	24 hrs	150	276	4	43	34	68	31
	Annual	60	7	0	1	1	1	1
Sox	1 hr	300	1322	41	352	302	292	192
	8 hrs	-	622	16	132	104	91	94
	24 hrs	125	393	6	61	48	97	44
	Annual	50	9	0	1	1	0	1

The statistical analysis for the results especially the standard deviation which give more understanding for the variability of a dataset. The std. dev. is low for all parameters which mean the data set are closed to the mean value, the highest value is 726 for PM10 at 1hr, this value still low when it compared with the total number of measured points: 10000 points. Also, the std. dev. of annual concentration for all parameters is very low (1:5) which prove the stability of pollutant concentrations

Graphical Presentation for results:

The following figures show that the graphical dispersion modeling results, which give very good presentation for how the emission fumes disperse over different times periods (1hr, 24 hrs. and annual).

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From the following figures, we will see the difference between dispersion effects with time, for the 1st hour of dispersion the pollutant comes with high level and wide dispersion area then the concentration of pollutant will be decreased with time and the dispersion area will start to confined area.

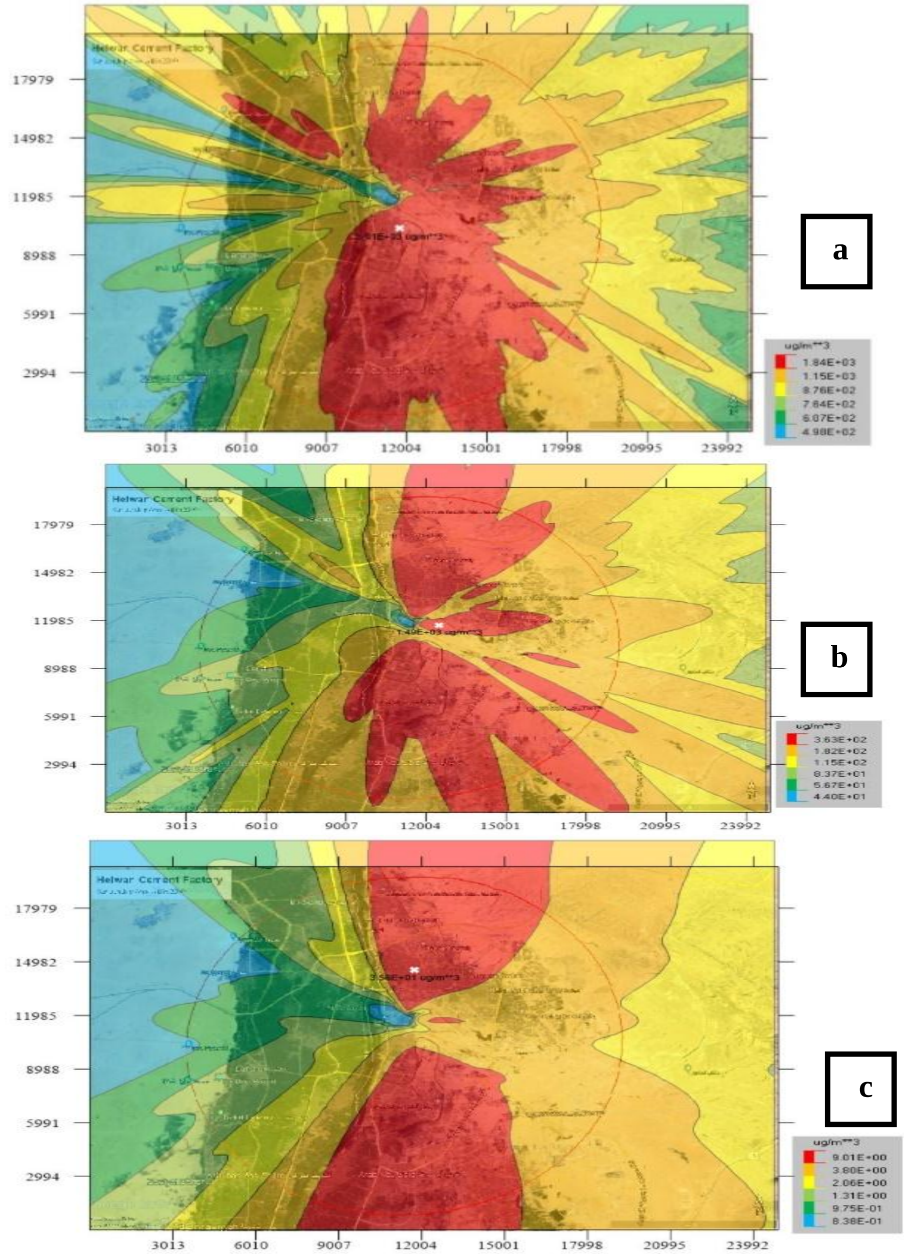

Figure 6: Graphical dispersion results of PM10 over (a) 1hr, (b) 24hr and (c) annual

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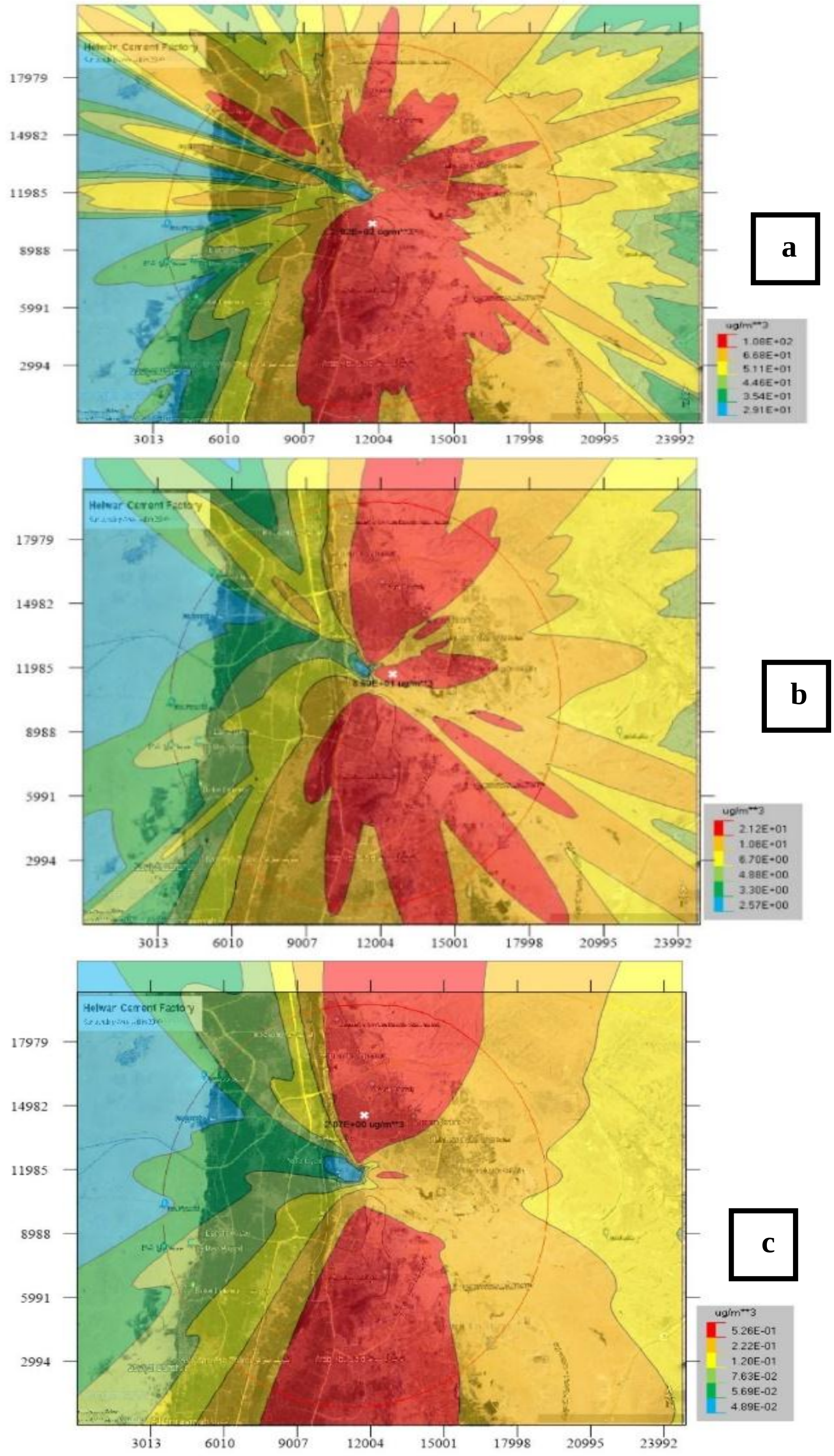

Figure 7: Graphical dispersion results of CO over (a) 1hr, (b) 24hr and (c) annual

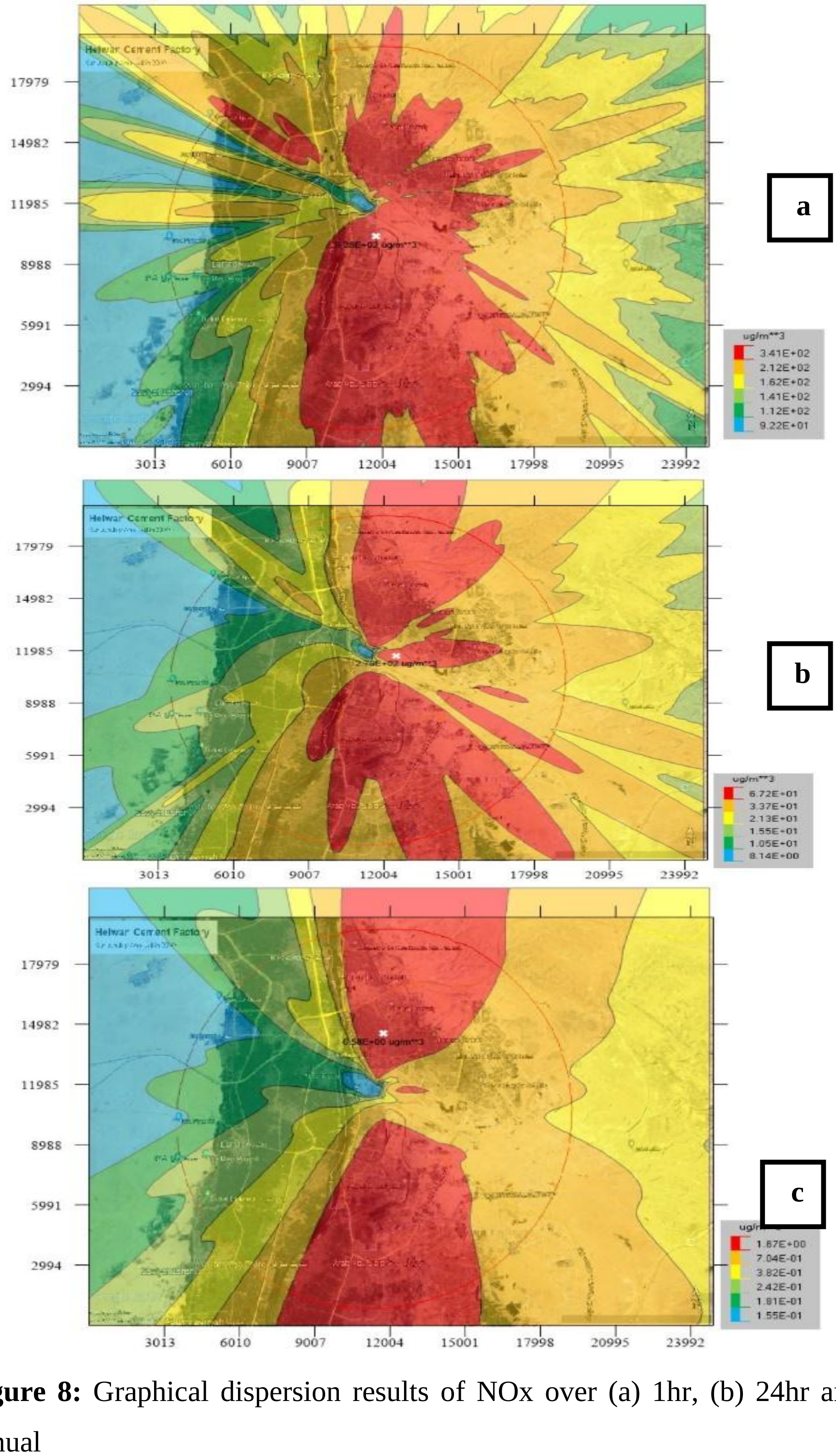

Figure 8: Graphical dispersion results of NOx over (a) 1hr, (b) 24hr and (c) annual

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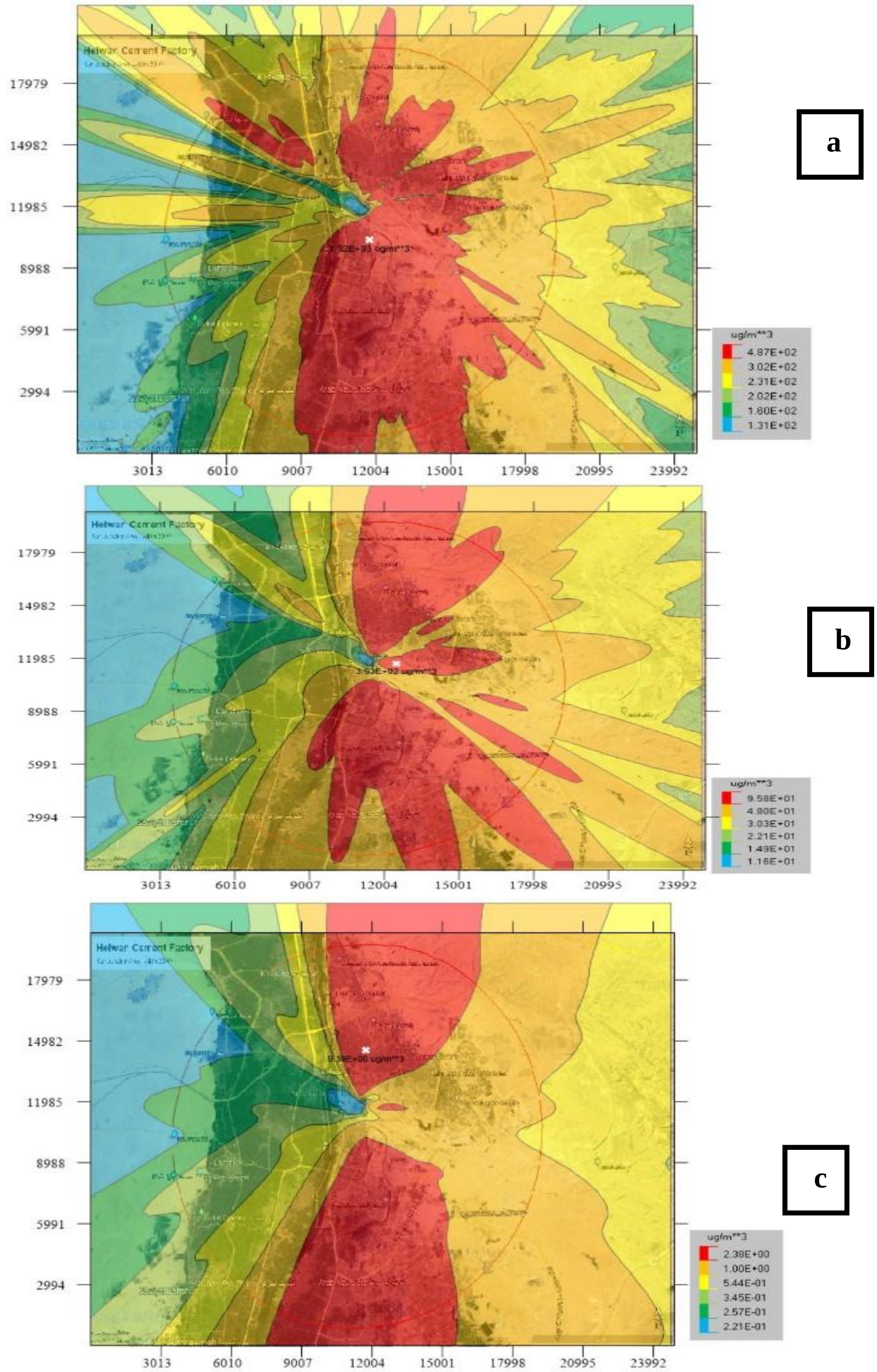

Figure 9: Graphical dispersion results of SOx over (a) 1hr, (b) 24hr and (c) annual

From the previous table and figures, it shows that:

- The level of PM10 emissions exceeding the low limits and the concentration points distributed for long distances within the surrounding area including the industrial, residential and agriculture regions.
- The level of NOx emissions exceeding the low limits for 1hr and the concentration points distributed for long distances within the surrounding area including the industrial, residential and agriculture regions.
- The level of SOx emissions exceeding the low limits for 1hr and the concentration points distributed for long distances within the surrounding area including the industrial, residential and agriculture regions.
- The level of CO emissions not exceeding the low limits and this is normal due to the high temperature of the combustion process.

CONCLUSION AND RECOMMENDATION

In this article, pollution level assessment carried out for pollutants resulting from cement plant using coal as a fuel (located at Helwan industrial area - Cairo Governorate – Egypt). Four of pollutants selected to study the level of pollution within the surrounding area: particulate matter with 10-micron PM10, carbon monoxide CO, sulfur oxides Sox and nitrogen oxides NOx. The assessment covers short-term (one hour) and long-term (annual) concentration level. The BREEZE AERMOD software used to measure or predict the pollutants concentration from studied cement plant (that used coal as a fuel) in the surrounding area within circle has diameter 20 km around the cement plant. The results show that, there are high level of concentrations for PM10, SOx and NOx emissions and high dispersion area covering industrial, residential and agriculture regions. The article recommends that, now days most heavy industries in Helwan near to residential area had been stopped except for cement plant so it is recommended to move this plant to another industrial zone far away from residential areas to avoid the high negative impact on environment, health and life quality for the surrounding areas.

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استخدام برنامج نمذجة جودة الهواء في تقييم مستوى التلوث بصناعة الأسمنت (دراسة حالة على منطقة حلوان الصناعية)

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مستخلص البحث

يعتبر الفحم جزءًا أساسيًا من إنتاج الطاقة ، لذلك كان من المهم إعادة تقييم المعايير والمتطلبات البيئية لتشمل جميع الأنشطة المتعلقة باستخدامه ، وكذلك فحم الكوك البترولي. تشتهر مصانع الأسمنت بإنتاج انبعاثات خطيرة مثل أول أكسيد الكربون والجسيمات الصلبة المستنشقة في حدود ١٠ ميكرون وأكسيد الكبريت وأكاسيد النيتروجين خاصة في منطقة حلوان حيث توجد العديد من الصناعات. لذلك كان من الضروري حساب مستويات التلوث البيئي بالمنطقة. الهدف الرئيسي من هذه الدراسة هو استخدام النماذج الرياضية، وتحديداً برمجيات نمذجة التشتت AERMODBreez e ، لقياس الأثر البيئي لاستخدام الفحم كوقود بديل بدلاً من الغاز الطبيعي. يتضمن ذلك فحص موقع منطقة حلوان ، وتحديد المستقبلات الحساسة، وتحديد مستوى التلوث الناتج عن صناعة الأسمنت. تستخدم الدراسة برنامج AER MOD للتنبؤ بالانبعاثات وتحليلها وتأثيرها على جودة الهواء. ستساهم نتائج هذا البحث في فهم الآثار البيئية لاستخدام الفحم كوقود بديل في صناعة الأسمنت ويمكن أن تساعد في تطوير استراتيجيات للتخفيف من التلوث.

غطت النمذجة تشتت جميع الملوثات على مدى ساعة – ٢٤ ساعة – سنة مع التركيز على أقصى تركيز مقارنة بالحدود المنصوص عليها في القانون في البيئة المحيطة. يستعرض البحث في فصولها منهجية العمل ونتائج تشتت جميع الملوثات في ساعة واحدة و ٢٤ ساعة وسنويًا (مقارنة بالحدود المنصوص عليها في القانون). عرضت النتائج بالطريقة الرقمية وكذلك بطريقة الخرائط البيانية لجميع الملوثات المعنية.