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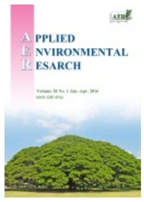

Assessment of Emissions from Cement Plants Using AERMOD Modeling

Atef I. Abdel-Gawad[1], Mahmoud NourEldeen[2], Hamada Mahmaoud[3], Asmaa S. Hamouda[1,*]

[1] Environmental Sciences and Industrial Development Department, Faculty of the Postgraduate Studies for Advanced Sciences (PSAS), Beni-Suef University, Beni-Suef, Egypt
[2] Central Laboratory, Egyptian Environmental Affairs Agency, Egypt
[3] Faculty of Science, Beni-Suef University, Beni-Suef, Egypt
[*] Corresponding author: asmaa_hamouda@yahoo.com

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Abstract

Coal combustion generates many gases and emissions which are harmful to public health and the environment. So, it is necessary to assess the health risks for the people living in the nearby cement plants that use coal as a fuel. In this article, a health risk assessment HRA was carried out concerning the air emissions from a cement plant in the heavy industry area located at Beni Suef governorate - Egypt. The article handles the assessment of the health risks for pollutants classified as non-carcinogenic i.e. sulfur dioxide - mercury and the health risks for pollutants classified as carcinogenic i.e. arsenic – chromium VI. An Air dispersion modeling program AERMOD is used to measure and evaluate long and short terms health impacts to expect the concentration of pollutants at the ground level within 30 km radius of the studied cement plant. The emissions measurements findings are used as input to the model in addition to some factors such as meteorology and surrounding terrain. Consequently, the program can implement simulations for the emissions concentration level of the mentioned pollutants and their effects on the population at Jazirat Abu Salih village, which is 10 km far from the studied cement plant. The results for mentioned pollutants concentrations levels matched with acceptance and safe levels of ambient air quality standards. In addition, the increment lifetime cancer risk ILCR by inhalation was calculated for arsenic and chromium and all results conformed with the safe and accepted limits.

Keywords: AERMOD; Cement plant; Health risks; Coal

Introduction

The cement industry has recently increased in Egypt; due to the availability of raw materials used in the industry in different places. Most of the cement plants use natural gas as a fuel in the kilns to produce the clinker – an intermediate product - which is then ground 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

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such as coal [1]. In. recent years; many countries, including Egypt, have faced difficulties in providing energy sources, such as natural gas; though. As a result, this is led to a sharp rise in the prices, which forced many cement plants to provide other sources of fuel at lower prices, such as coal. This, in turn, led to a noticeable change in the rates of emission of pollutants into the environment, and consequently necessitated studying the health risks of 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 health risks to 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 implement health risk assessment to the people near the studied cement plant that used coal as a fuel, whether in the long or in the short term, using the air dispersion modeling. 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 regulations. To carry out the health risk assessment, four pollutants resulting from the emissions of the stack of the cement plant were selected: two of them are sulfur dioxide and mercury which are classified as non-carcino-genic pollutants, and the other two pollutants are arsenic and chromium which are classified as carcinogenic pollutants. There are many methods to implement the health risks assessment for the emissions from cement plants. However, in this study, the 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. Although there are several studies and research on health risks assessment for heavy metals effects in different areas in Egypt, health risks assessment for heavy metals by inhalation was not addressed using the dispersal modeling program (most of the modeling studies dealt with the estimation of some non-carcinogenic pollutants such as nitrogen dioxide, sulfur dioxide, and carbon monoxide) [4]. In the case of studying forecasts of dispersion of pollutants concentration using air dispersion modeling, the health risks assessment is usually done [5–6].

Materials and methods

1) The studied cement plant

The studied cement plant is located northeast of Beni Suef governorate, at the heavy industrial area. The site includes one 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 2019. It is worth mentioning that all measurement devices have an updated calibration certificate. The studied cement plant is located in an uninhabited desert area, where the nearest community is located 10 km far from the plant and called Jazirat Abu Salih Village. According to the last update of statistics from the Egyptian Central Agency of Statistics, the village population is 5,362. Moreover; there are no human communities around the studied cement plant except Jazirat Abu Salih Village. The only building that we can find around the studied cement plant is an old industrial facility that stopped production for a long time. The only source of drinking water for all people in the village is the water from the river Nile after treatment in a water treatment plant. There is a difficulty in growing crops in the areas between the studied cement plant and the village; due to the desert nature of the soil. The studied cement plant and the receptor are shown in Figure1.

Measurements of the emissions from the stack 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) [7].

Figure 1 Locations of (a) the studied cement plant, (b) the receptor - Jazirat Abu Salih Village.

2) Air dispersion modeling

The air pollutant dispersion modeling program AERMOD was published in September 2004 at the agency US EPA under the number of EPA-454/R-03-004 [8]. AERMOD version 4,300 is a way of expressing the effects on the surrounding environment resulting from the emission of pollutants from a specific source through mathematical equations arranged and organized by program. Furthermore, it has been updated and reset by ISCST3 the Industrial Source Complex Short-Term Modeling via entering some of the clearer equations and concepts [5]. 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. In the AERMOD program, the basic data is entered with other requirements such as meteorological data and land topography. When comparing the use of AREMOD program in environmental monitoring with the field measurements by taking periodic samples over a specified period, the advantages of using the program are as follows: reducing the time required to complete studies and the cost of work and effort for people. The program came out in 2004 by US-EPA, as a program used to simulate the dispersal of pollutants rates [8]. 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 health effects on the population near the source of pollution in a radius of 30 km [9], [10]. To use the air dispersion modeling program AERMOD the following items must be available in the input: AERMET meteorological, AERMAP landforms [11]. The clarification of details for running the AERMOD program is as follows: the modeling program makes an analysis for all AERMET meteorological data, and then uses AERMAP landforms with the average of emissions measurements results for identifying the maximum dispersal of every element. In addition, the steps to run the AERMOD program are shown in Figure 2.

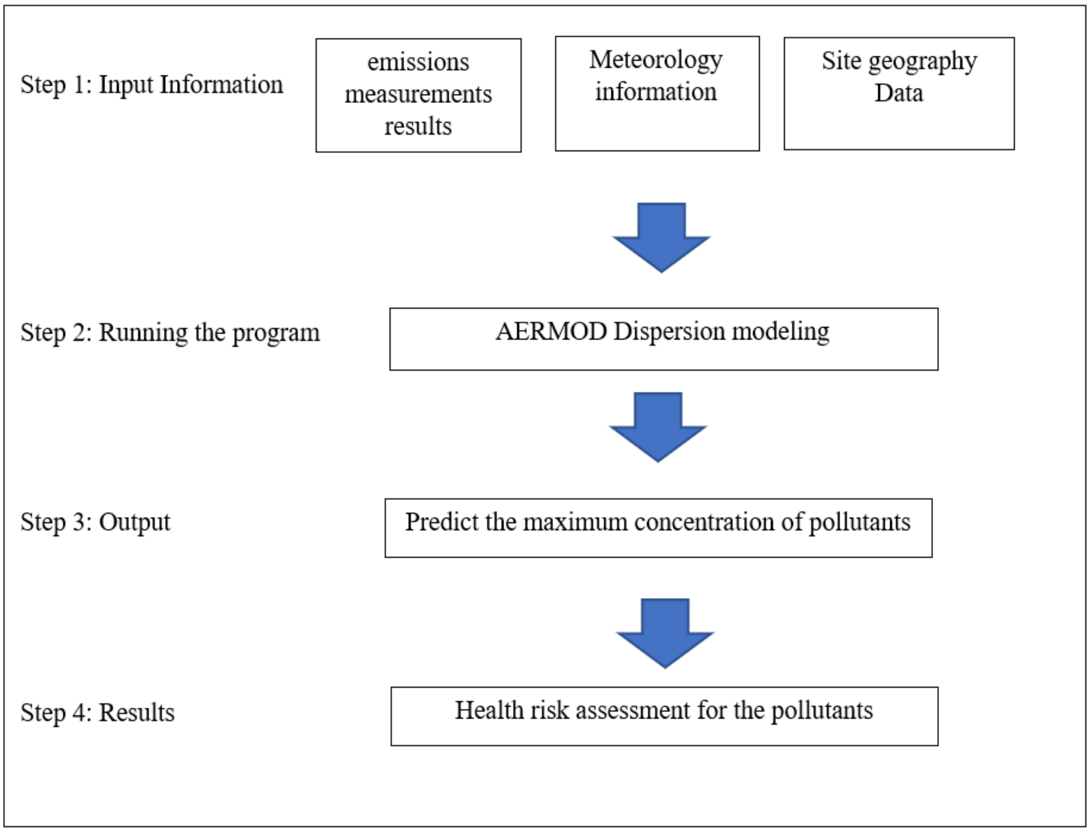

Figure 2 Steps of air dispersion modeling using AERMOD program.

3) Health risk assessment

Many researches have proposed a health risk assessment methodology such as health risk assessment for emissions of power plant in Malaysia [5], health risk assessment for emissions from Jamshoro thermal power station [12]. Health risk assessment (HRA) contains four steps in a row:

3.1) Hazards identification

The stack of studied cement plant releases air pollutants that may have a harmful effect on the health of communities in the areas around the plant, in addition to heavy elements such as arsenic and chromium. Furthermore, it was reported that it has a very harmful effect on human health [13–14]. In this article, four of the pollutants resulting from raw materials burning at industry process stages at the studied cement plant were selected to study the health risk assessment: two of them have a carcinogenic effect on human health: arsenic and chromium, and the other two are non-carcinogenic elements: sulfur dioxide and mercury [5]. The total sulfur at the coal that used as a fuel at the studied cement plant (shipment of coal arrived in December 2018) is 0.73 % (dry basis). The plant did not have any gas pollutants control (for sulfur gases). It is removed directly during the process steps. For example, the sulfur dioxide decreased at the stack emissions by the chemical reaction between sulfur dioxide and calcium oxide - that already found in the raw materials - in the preheater area and cement kiln where calcium sulfite is produced [11]. There are a lot of filtrations systems used to control the dust emissions from all production process steps: more than 57 cement bag filters were fixed on the production line, also two electrostatic precipitator filters were used in the raw materials and cooler areas.

3.2) People's response for the dose

It is a quantitative process to determine the relationship between exposure to dose risk and the appearance of adverse effects. Some terms are used such as: reference dose (RfD), and reference concentration (RfC) [5, 15]. The RfD is the amount of a person's daily exposure to the toxic substance through the mouth, while the RfC is the concentration of the toxic substance in the air that a person can tolerate in a day without a harmful effect on his health [15]. If RfC does not exist or is difficult to obtain, then it is possible to use RfD instead of it for assessment as follows Eq. 1. [5].

3.3) Assessment of people's exposure to pollutants

AERMOD is a program used to predict the exposure of people in the vicinity of the studied cement plant to the pollutants resulting from the burning of raw materials during the cement manufacturing stages [13]. AERMOD program was run to obtain maximum air pollutants concentration within one hour to determine the health effects of pollutants in the short term. Furthermore, the program was run to obtain the maximum air pollutants concentration for air pollutants annually to determine the long-term health effects [6, 13].

$$\text{Inhalation RfC } (\mu g/m^3) = \frac{\boldsymbol{OralRfD(mg/kg.day)\ 70kg}\ BW\ \mathbf{1000}\ \boldsymbol{\mu g/mg}}{\mathbf{20}\ \boldsymbol{m3\ /\ day\ Inh.rate}} \qquad \text{(Eq. 1)}$$

where; RfD: is daily estimate of exposure to toxic substances through mouth [16] and BW is the body weight.

3.4) Risk description

The health risks of pollutants are divided into two categories: carcinogenic health risks or non-carcinogenic health risks [5, 17]. The non-carcinogenic health risks due to inhalation were described by determining the quantifying of the risks using the hazard quotient (that it will mention on Eq. 2 by: HQ inhalation) which was identified as follows: [5, 18–19].

$$\text{HQ inhalation} = \frac{EC(\mu g/m3)}{RFC(\mu g/m3)} \quad \text{(Eq. 2)}$$

where; EC is exposure to air concentration (μg m^{-3}) and RFC is reference concentration (μg m^{-3}).

It is known that the calculation of exposure of air concentration EC is done by a mathematical equation [19], but some researches such as health risk assessment for coal-fired power plant in Malaysia [5] and health risk assessment for Jamshoro power station [20] used AREMOD program for carrying out health risks assessment. The exposure of air concentration EC is calculated by the AREMOD program by entering the emissions measurements of the stack with the rest of the information required in the input of the program. If the hazard quotient - HQ inhalation - is less than one, this means that the concentration value for the pollutant is less than reference concentration [21]. This, in turn, indicates that the potential risk of the pollutant is at an acceptable and safe level, with no need to take any measures to reduce the pollutant level [19]. Exposure to heavy metals is one of the important causes of cancer, as exposure is carried out in several ways including the following ones: inhalation, swallowing, or contact through the skin. Some researches stated that exposure to heavy metals through inhalation is more effective than ingestion and dermal, especially for elements that are from the source of gaseous emissions from manufacturing processes [22], so this study is focused on the health risks assessment of heavy metals through inhalation for the nearest residential community to the studied cement factory, which is 10 km away. In addition to the possibility of exposure through ingestion and dermal is low, the root causes for this are: there are not any agricultural activities at the effective area between the studied cement plant and the nearest community area, also the main source for drinking water is the water from the river Nile after treatment within a treatment plant far from the village. The two elements arsenic and chromium were selected in this article, as they are the highest elements in the emission rate from the stack of the studied cement plant, which will be important that study the rest of the elements in the event there are health effects of these two elements on the nearby population. For health risks assessment of the carcinogenic elements by inhalation. We should calculate the lifetime cancer risk (LCR) for the pollutant. The LCR is known by the following Eq. 3 [5, 18–19].

$$\text{LCR} = \text{EC URF} \quad \text{(Eq. 3)}$$

where; URF: is unit risk factor (μg $m^{-3})^{-1}$ and EC: is exposure of air concentration (μg m^{-3}).

The acceptable and safe standard for the threshold value of cancer risk is 10^{-6} (1 per 1,000,000) [5, 23]. Most of the studies that were carried out on the health risks assessment of heavy metals in Egypt were conducted on estimating the extent of soil contamination with heavy metals [23], in addition to not specifying LCR in most studies. Some research has been used entirely on the study of LCR in determining the risk of cancer exposure to heavy metals in the long term [5] however, it is necessary to check the extent of the possibility of exposure to cancer in the long term from inhalation of heavy metals on the emissions of the studied cement plant, this can be studied by the incremental lifetime cancer risk (ILCR) for the elements of arsenic and chromium, the following Eq. 4 will clarify ILCR inhalation [24].

The ILCR represents the lifetime risk of people developing of cancer by inhaling heavy metals. The results can be divided into two groups: The first group, the first group: ILCR $\leq 10^{-6}$ acceptable risks, the second group: ILCR $> 10^{-3}$ unsafe and unacceptable risks [25].

$$\text{ILCR inhalation} = \frac{C\ ET\ EF\ ED\ IR}{BW\ AT} CF\ CSFi \quad \text{(Eq. 4)}$$

where; C: heavy metal concentration (mg m^{-3}), IR: inhalation rate (1.3 m^3 h^{-1}) [25], EF: exposure frequency (365 d a^{-1}), ET: exposure time (24 h d^{-1}), ED: duration of exposure, IR: inhalation rate, for children is (12.69 m^3 d^{-1}) and for adults is (20.64 m^3 d^{-1}) [24], BW: body weight for children is (34.05 kg) and for adults is (70 kg) [24], AT: average time (75.5 x 365 days) [24], CF: conversion factor (10^{-6}) [24], CSFi: cancer slope factor for inhalation (kg – d mg^{-1}) and the CSFi was calculated by Eq. 5.

$$\text{CSFi} = \frac{IUR\left(\frac{mg}{\mu g}\right) 1000 \left(\mu\frac{g}{mg}\right)}{\frac{BW(kg)}{IR\left(\frac{m3}{d}\right)}} \quad \text{(Eq. 5)}$$

Results and discussion

1) Information about air pollutants of the studied cement plant

It is known that the cement plant is one of the most polluting industries to the environment in a large way, unless necessary precautions are taken to prevent or reduce these pollutants [26]. The environmental measurements were implemented for the emissions from the stack of studied cement plant and the average of pollutants during 2019 were recorded in Table 1, according to the standards in the Egyptian Environmental Law 4/1994 (and its amendments by Law 9/2009).

The emissions that including some pollutants e.g. arsenic and chromium may have a carcinogenic effect on human health [13, 26]. In accordance with international US-EPA, method 8 was used for sulfur dioxide measurements and the following is the summary of the method steps: The gases sample is extracted from the stack, where all the components of the sulfur gases are extracted together and then separated by the barium-thorin titration method [27]. The international US-EPA - method 29 was used to measure the heavy elements: The sample of gases is extracted from the stack, where all the components of the gases are extracted on a hot filter, after that the sample is divided into two parts: the first one is dissolved in an acidic solution of potassium permanganate to dissolve mercury, while the second part is dissolved in an acidic solution of hydrogen peroxide (for all heavy elements including mercury), all samples are digested and the elements - except mercury- are estimated by argon coupled plasma argon emission spectroscopy. For mercury, it is estimated by cold, atomic vapor [27]. Also, international US-EPA - method 61 was used to measure chromium VI, where the gas sample is collected on a cellulose filter saturated with sodium carbonate, then the chromium VI is extracted by sodium bicarbonate, where it is separated by diphenyl carbazide solution [27].

Table 1 Air emissions measurements results for the studied cement plant

Pollutants	Units	Average concentration	Maximum limits according to Egyptian Law
Sulphur dioxide	mg m^{-3}	130.25	400
Nitrogen oxides	mg m^{-3}	870.25	600
Carbon monoxide	mg m^{-3}	70.01	Nil
Total particulate matter (dry)	mg m^{-3}	34.26	50
Mercury	mg m^{-3}	0.003225	0.05
Arsenic	mg m^{-3}	0.02091	Nil
Chromium VI	mg m^{-3}	0.01879	Nil
Cadmium	mg m^{-3}	0.00179	Nil
Nickel	mg m^{-3}	0.00169	Nil
Lead	mg m^{-3}	0.00192	Nil

2) Study the results of using a modeling program

When assessing the climate conditions in Beni Suef government (the area of studied cement plant), we found that the area is affected by prevailing southwest winds. Furthermore, the summer season is characterized by dry and hot season and mild winter season [28], Figures 3 to 6 show the maximum concentration for sulfur dioxide, mercury, arsenic and chromium dispersion rate on 1 h and annual average basis is conducted by AREMOD program. The receptor is Jazirat Abu Salih Village located 10 km west of the studied cement plant. Each figure showed the maximum dispersal for the element in short term and long term. Each figure included the results number of the dispersion modeling. On the following figures the letter (a) refers to the studied cement plant, while the letter (b) refers to the receptor.

The maximum levels of concentration for pollutants that are used at the air modeling system during both periods: short term and long term are shown in Table 2.

When comparing the pollutant concentrations resulting from the studied cement plant with the Egyptian Environmental Law 4/1994 (and its amendments by Law 9/2009) [7], and other regulations i.e.: Alberta, Arizona and New Zealand AAQG [29–31], it became clear that people who live in a radius of 10 km from the studied cement plant are exposed to very low, acceptable and safe concentrations of pollutants. Some of the other international regulations have been used as references because there are no safe limits found in the Egyptian environmental law for some elements such as mercury, arsenic and chromium. It is noted that the annual concentration of chromium is 0.00008 μg m^{-3}, and this is equal to the permissible limits in the Arizona -AAQG regulation 0.00008 μg m^{-3}, this, in turn, indicates the need for more evaluations to determine whether there is a possibility of actual harm for the health of people in the area near the studied cement plant.

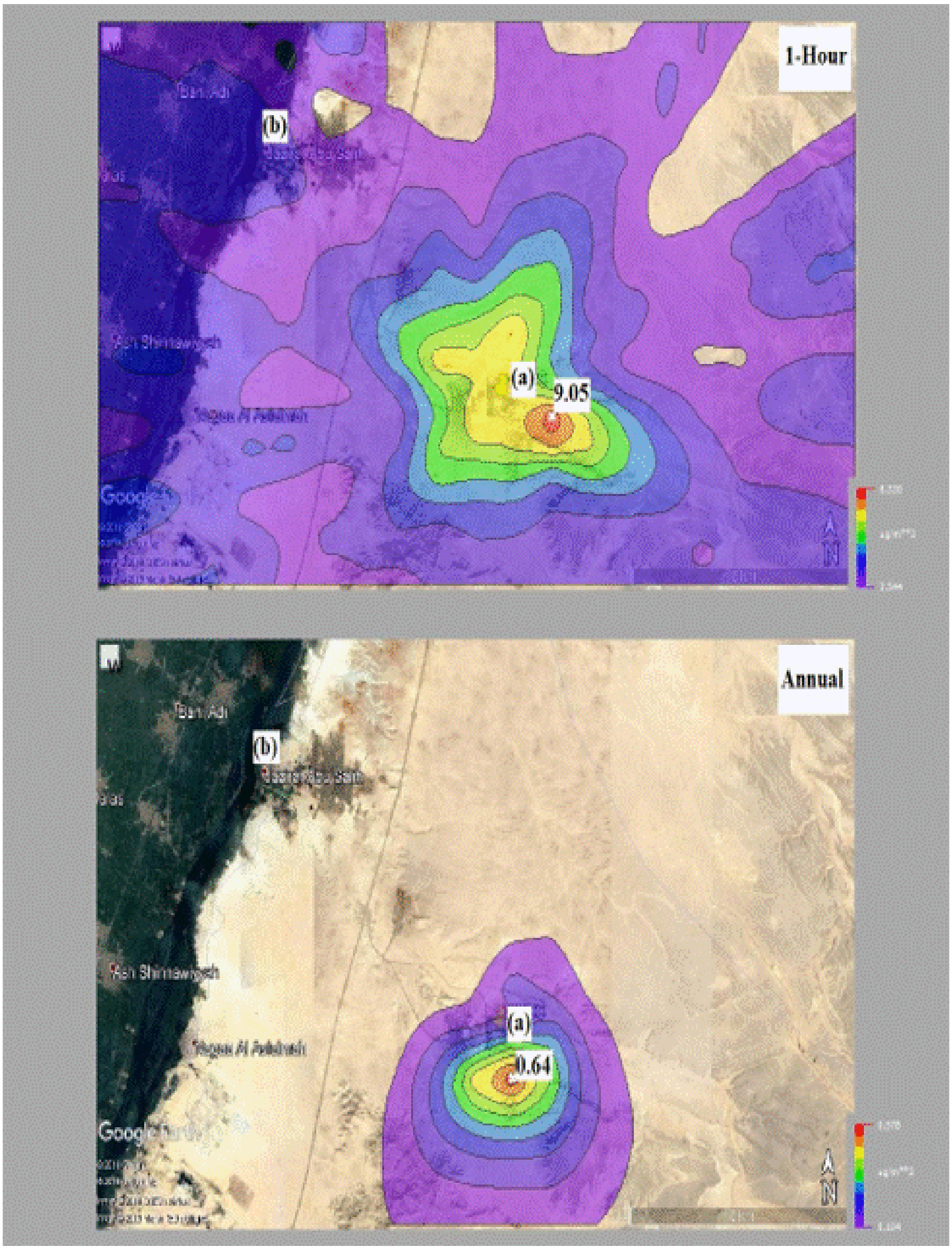

Figure 3 Average of sulfur dioxide concentration measured at (a) the cement plant and (b) the receptor - Jazirat Abu Salih Village.

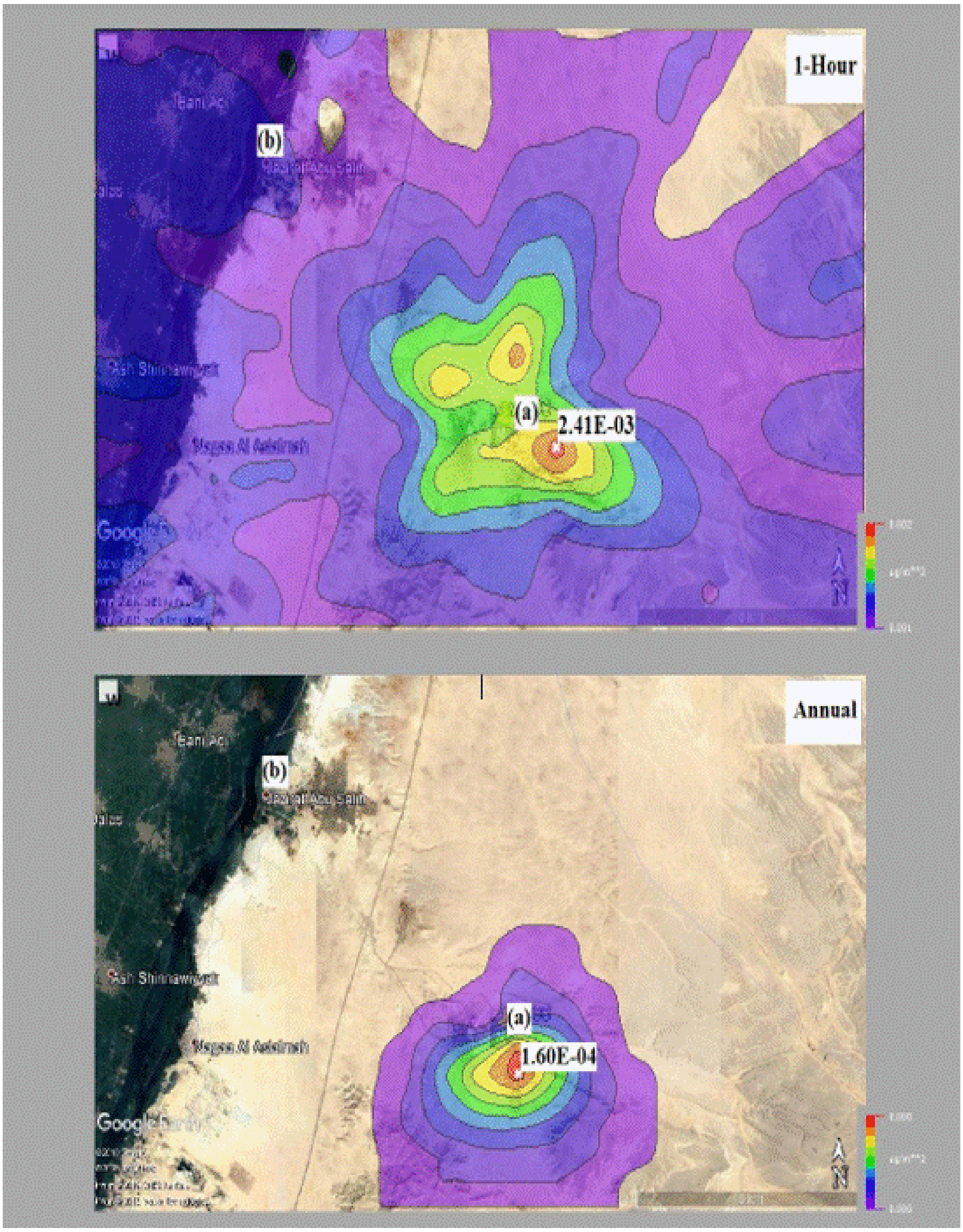

Figure 4 Average of mercury concentration measured at (a) the cement plant and (b) the receptor - Jazirat Abu Salih Village.

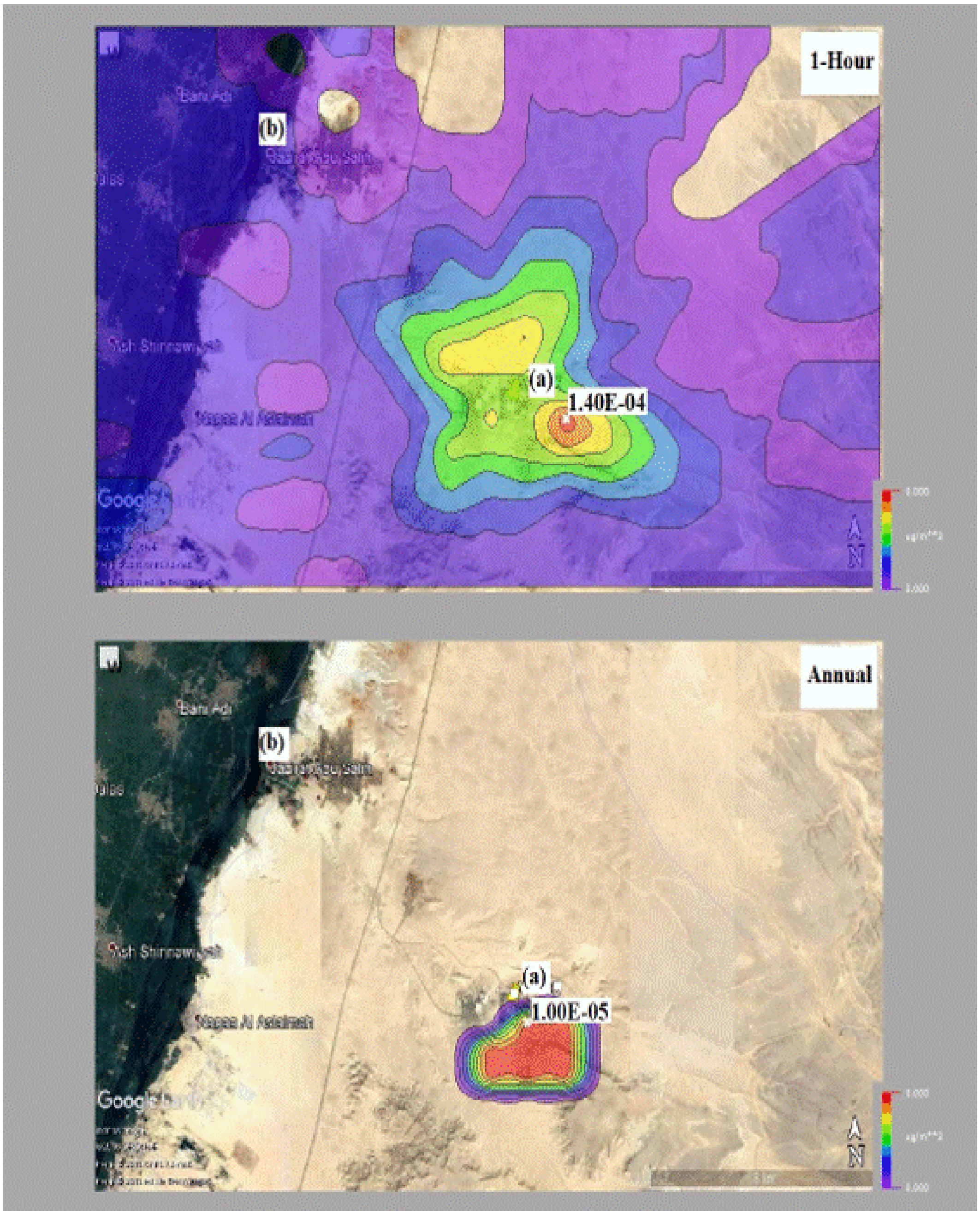

Figure 5 Average of arsenic concentration measured at (a) the cement plant and (b) the receptor - Jazirat Abu Salih Village.

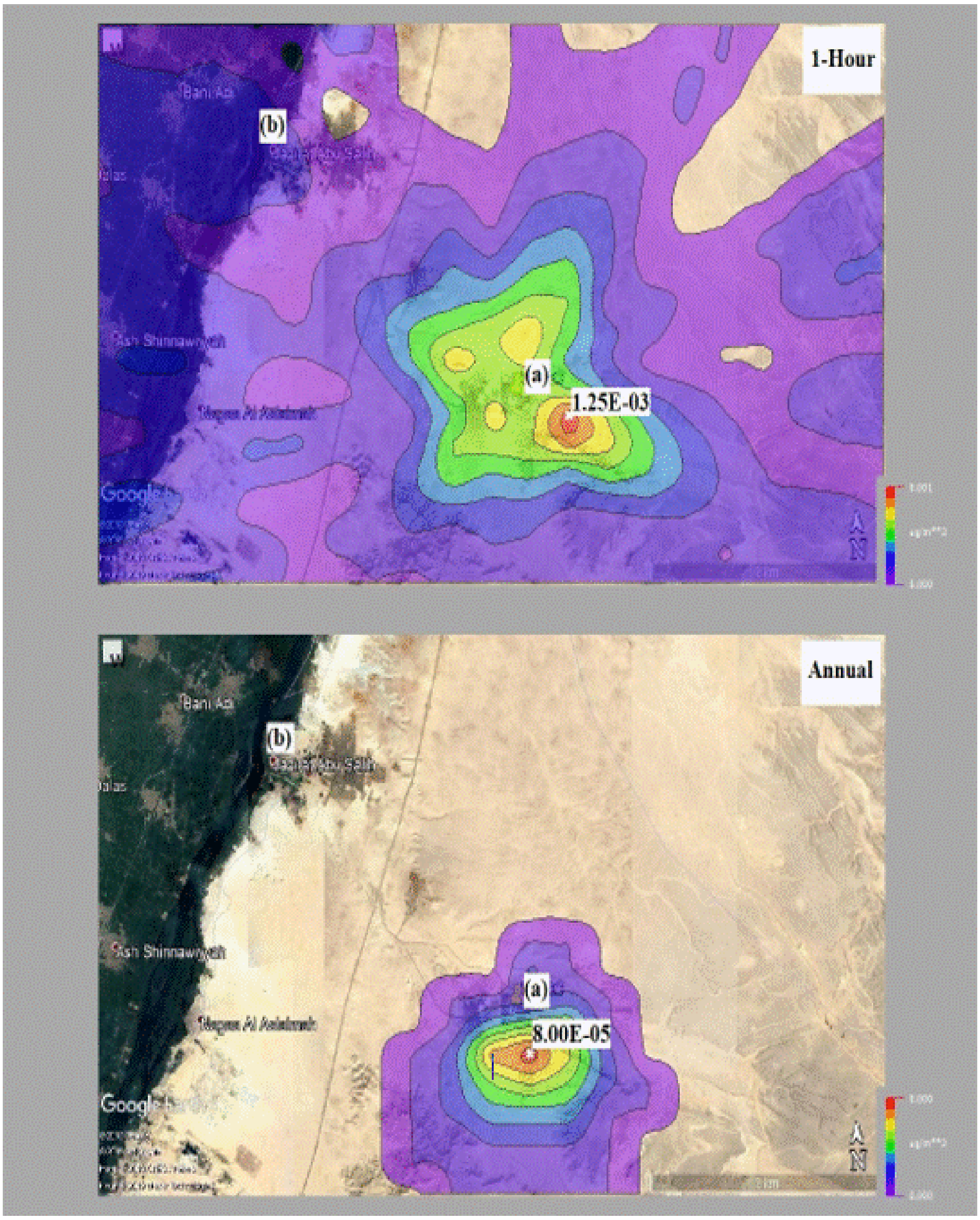

Figure 6 Average of chromium VI concentration measured at (a) the cement plant and (b) the receptor - Jazirat Abu Salih Village.

Table 2 Comparison between expected maximum GLC and AAQG

Pollutants	Average of concentration (One-Hour) (µg m^{-3})	guideline of (One-hour) ambient air (µg m^{-3})	Average of concentration (Annual) (µg m^{-3})	Ambient air quality guideline (Annual) (µg m^{-3})
Sulfur dioxide (Non-carcinogenic)	9.05	350 [a]	0.64	60 [a]
Mercury (Non-carcinogenic)	0.0024	1.5 [c]	0.00016	0.33 [d]
Arsenic (carcinogenic)	0.000014	0.1 [b]	0.00001	0.01 [b]
Chromium VI (carcinogenic)	0.00125	0.1 [c]	0.00008	0.00008 [c]

Note: [a] Egyptian Air Quality Limits – (Egyptian Environmental Law 4/1994-and its amendments by Law 9/2009), [b] Alberta AAQG, [c] Arizona AAQG and [d] New Zealand AAQG

3) Studying the health risks of non-carcinogenic elements

Hazard quotient (HQ) is calculated for each of the sulfur dioxide and mercury to identify the health risks for them in the long term and in the short term, as they are non-carcinogenic elements [5, 32]. Moreover, HQ was calculated for the mentioned elements during a year and within one hour, and all results were given in Table 3.

After studying the HQ for sulfur dioxide, the dispersion in the short term 0.362 and in the long term 0.025 is less than one. Consequently, the concentration of pollutants is within the permissible safe limits. For mercury, and after studying its dispersion, it became clear that the HQ in the short term 0.008 and in the long term is 0.00053. Owing to the fact that it is less than one, this confirms that mercury concentration in the long term and in the short term is within the safe and permissible limits for people residing in areas near the studied cement plant [5, 19]. By comparing the HQ for the studied cement plant with another facility that uses the same type of fuel, "coal", e.g. electrical power plant in Malaysia [5], the following was observed: The HQ for sulfur dioxide during the short term is 1.8 which is not acceptable and is not safe level according to US- Human Health Risk Assessment Protocol 2005 [18], but it is acceptable from the studied cement plant 0.362. The root cause for the low level of sulfur dioxide at the studied cement plant is the chemical reaction between sulfur dioxide and calcium oxide (that is already found in the raw materials) in the preheater area and cement kiln where “calcium sulfite” is produced. This, in turn, reduces the emission of sulfur dioxide to the ambient air [11]. Although the HQ for sulfur dioxide during the long term is 0.1 for an electrical power plant in Malaysia [5], and for the studied cement plant 0.025, it is still within the safe limits and acceptable according to US - human health risk assessment protocol 2005 [18].

4) Studying the health risks for carcinogenic elements

Some of the pollutants have carcinogenic effects for the human such as arsenic and chromium. A lot of researches indicated that it has harmful effects on kidneys, skin and bones [35]. The rate of exposure to these carcinogenic elements is higher in the case of inhalation than in other methods of exposure such as ingestion or through the skin [36]. The lifetime cancer risk (LCR) is calculated for arsenic and chromium to identify the health risks for them in the long term and in the short term as they are carcinogenic elements [5, 20], where LCR was calculated for the mentioned elements during a year and within one hour. All results are given in Table 4.

After studying LCR the risk of developing cancer for people that living near the studied cement plant - Jazirat Abu Salih Village - located 10 km west of the emissions source, the following are the results:

At short-term: LCR for arsenic and chromium are 0.6×10^{-7} and 1.5×10^{-5}.

Also, the long-term: LCR for arsenic and chromium are 0.42×10^{-7} and 9.6×10^{-5}.

As we mentioned before, the acceptable and safe standard for the threshold value of cancer risk is LCR = 10^{-6} 1 per 1,000,000 [5, 23]. The results for LCR calculation for both arsenic and chromium during the short-term and the long-term indicate that there is no possibility of developing cancer as a result of exposure to pollutants arsenic and chromium resulting from the studied cement plant, for the population living near it - Jazirat Abu Salih Village - located 10 km west of the emissions source. By comparing the LCR for the studied cement plant (that uses coal as a fuel) with another facility that uses the same type of fuel "coal", e.g. electrical power plant - Malaysia [5], the following was observed:

The LCR for arsenic and chromium is higher than their threshold limits 1×10^{-4} & 1×10^{-6} during short term. This, in turn, reveals that people living in the area within a 10 km radius of the electric power plant are at risk of developing cancer. But in the studied cement plant, there is no possibility of developing cancer as a result of exposure to pollutants arsenic and chromium resulting from the studied cement plant, for the population living near it. To further confirm that the ILCR inhalation was calculated for both arsenic and chromium to study the possibility of cancer by inhalation in the long term, the following results were concluded: ILCR inhalation for arsenic: children: 9.4×10^{-8}, and for (adults): 1.6×10^{-6} also the ILCR inhalation for chromium: children: 8.5×10^{-8} and for (adults): 1.044×10^{-6}. It is clear from the results that all ILCR inhalation for arsenic and chromium conformed with the USEPA limits (ILCR $\leq 10^{-6}$) and in the acceptable health risks for children or adults. A similar study was conducted in Poland on the same elements taken in this study: arsenic and chromium. However, the results of the ILCR inhalation were different, owing to the fact that there was a possibility of exposure to cancer as a result of exposure to arsenic and chromium by inhalation in different age groups is large proportions [24].

Table 3 Health risks impacts form non-carcinogenic pollutants (studied cement plant)

Pollutant	Expected EC (µg/m^3)		Reference concentration (RfC) (µg m^{-3})	Hazard quotient (HQ)	
	Short-term (One-hour)	Long-term (Annual)		Short term (One -hour)	Long term (Annual)
Sulfur dioxide	9.05	0.64	25 [a]	0.362	0.025
Mercury	0.0024	0.00016	0.3 [b]	0.008	0.00053

Note: [a] ATSDR [33], [b] US EPA Guidelines for Carcinogen Risk Assessment [34].

Table 4 Health risks impacts form carcinogenic pollutants (studied cement plant)

Pollutant	Predicted ambient air exposure (μg m^{-3})		Unit risk factor - Inhalation (URF) (μg m^{-3})	Excess lifetime cancer risk (LCR)	
	Short-term (One-hour)	Long-term (Annual)		Short-term (One-hour)	Long-term (Annual)
Arsenic	0.000014	0.00001	4.29 x 10^{-3} [a]	0.6 x 10^{-7}	0.42 x 10^{-7}
Chromium VI	0.00125	0.00008	1.2 x 10^{-2} [a]	1.5 x 10^{-5}	9.6 x 10^{-5}

Note: [a] US EPA Guidelines for Carcinogen Risk Assessment [37].

Conclusions

In this article, health risks assessment was implemented for pollutants resulting from cement plant using coal as a fuel (located at the heavy industry area - Beni Suef Governorate – Egypt). Four of the pollutants were selected to study the health risk assessment: two of the pollutants were classified as carcinogenic: arsenic and chromium, while the other two pollutants were classified as non-carcinogenic: sulfur dioxide and mercury. The assessment covers short-term (one hour) and long-term (annual) health effects. The AERMOD modeling program was used to measure and expect the pollutants concentration from studied cement plant (that used coal as a fuel) in an area of 30 km by 30 km. Moreover, the increment lifetime cancer risk ILCR inhalation was calculated for arsenic and chromium and all results conformed with the safe and accepted limits. After comparing the results with the Egyptian environmental law and international environmental regulations, it became clear that the populated areas located within a 10 km distance from the studied cement plant - Jazirat Abu Salih Village - are exposed to a very low and safe level of carcinogenic and non - carcinogenic pollutants concentration (in the short the long terms).

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References

[1] Schakel, W., Hung, C., Tokheim, L., Stromman, A., Worrell, E., Ramirez, A., Impact of fuel selection on the environmental performance of post-combustion calcium looping applied to a cement plant. Applied Energy, 2018, 210, 75–87.

[2] John, J., Parametric studies of cement production processes. Journal of Energy, 2020, 4289043.

[3] Hua, S., Tian, H., Wang, K., Zhu, C., Gao, J., Ma, Y., …, Zhou, J. Atmospheric emission inventory of hazardous air pollutants from China's cement plants: Temporal trends, spatial variation characteristics and scenario projections. Atmospheric Environment, 2016, 128,1–9.

[4] Tolba, R., Abou-Shleel, M.A., El-Mohandes, M., El-Shirbeny, M., Assessment open rice straw burning impacts on air quality of great Cairo based on dispersion models, biochem.2020, 15(1), 1–20.

[5] Mokhtar, M., Hassim, M., Taib, R. Health risk assessment of emissions from a coal-fired power plant using AERMOD modeling. Process Safety and Environment Protection,2014, 92, 476–485.

[6] Noorpoor, A., Rahman, H., Application of AERMOD to local scale diffusion and dispersion modeling of air pollutants from cement factory stacks (Case study: Abyek Cement Factory). Pollution, 2015, 1(4), 417–426.

[7] Egyptian Environmental Affairs Agency. Ministry of environment - Egypt. Law 9/2009 (updating of law 4/1994). Cairo, Egypt. 2009. [Online] Available from: http://www.eeaa.gov.eg/en-us/laws/envlaw.aspx [Accessed 25 June 2021].

[8] Abdelaal, A., Safwat, H., Beheary, M., Assessing and modelling of some air emissions produced from mopco fertilizers, Damietta, Egypt. Alfarama Journal of Basic & Applied Sciences, 2020, 1(2), 123–136.

[9] Fadavi, A., Abari, M., Nadoushan, M. Evaluation of AERMOD for distribution modeling of particulate matters (Case study: Ardestan cement factory). International Journal of Pharmaceutical Research & Allied Sciences, 2016, 5(4), 262–270.

[10] US EPA. United States Environmental Protection Agency. User's guide for the AMS/EPA regulatory model- AERMOD, Addendum. US EPA, 2021, [Online] Available from: https://www.epa.gov/ttn/scram/models/aermod/aermod_userguide.zip [Accessed 25 June 2021].

[11] Zhang, T., Wu, T., Li, B., Wang, J., Ravat, R., Chen, X., …, Yu, Q. Linking the SO_2 emission of cement plants to the sulfur characteristics of their 2 limestones: A study of 80 NSP cement lines in China. Journal of Cleaner Production, 2019, 220, 200–211.

[12] Shaikh, K., Imran, U., Shaikh, S., Health risk assessment for emissions from Jamshoro thermal power station using AERMOD dispersion model. Journal of Industrial Pollution Control, 2018, 34(2), 2142–2151.

[13] Bevan, R., Harrison, P., Threshold and non-threshold chemical carcinogens: A survey of the present regulatory landscape. Regulatory Toxicology and Pharmacology ,2017,88, 291–302.

[14] Kharazi, A., Leili, M., Khazaei, M., Alikhani, M., Shokoohi, R., Human health risk assessment of heavy metals in agricultural soil and food crops in Hamadan, Iran. Journal of Food Composition and Analysis ,2021, 100, 103890.

[15] Louvar, B. Louvar, J. Health and Environmental Risk Analysis. 1st Edition Prentice Hall PTR, 1997, 706.

[16] Shaikh, K. Imran, U. Shaikh, S. health risk assessment for emissions from Jamshoro thermal power station using AREMOD dispersion model. Journal of Industrial Pollution Control, 2018, 34(2), 2142–2151.

[17] Jayadipraja, E., Daud, A., Assegaf, A., Maming, M. The application of the AERMOD model in the environmental health to identify the dispersion area of total suspended particulate from cement industry stacks. International Journal of Research in Medical Sciences, 2016, 6, 2044–2049.

[18] US EPA, Office of solid waste. Human Health Risk Assessment Protocol for Hazardous Waste Combustion Facilities. U.S. Environmental Protection Agency. New York, USA. 2005. [Online] Available from: https://www.epa.gov/ [Accessed 25 June 2021].

[19] Maseki, J., Annegarn, H., Spiers, G., Health risk posed by enriched heavy metals (As, Cd, and Cr) in airborne particles from Witwatersrand gold tailings. The Journal of the Southern African institute of Mining and Metallurgy, 2017, 663–669.

[20] Makaremi, M., Mansouri, N., Rezavafaeinajad, A., Behzadi, M., Hossieni, S., Health risk assessment of emissions from a gypsum plant using AERMOD. Journal of Environment and Health Science, 2019, 5(2), 63–70.

[21] Shaikh, K., Imran, U., Shaikh, S., Health risk assessment for emissions from Jamshoro thermal power station using AERMOD dispersion model. Journal of Industrial Pollution Control, 2018, 4 (2), 2142–2151.

[22] Sawut, R., Kasim, N., Maihemut, B., Hu, L., Abliz, A., Abdujappar, A., Kurban, M., Pollution characteristics and health risk assessment of heavy metals in the vegetable bases of northwest China. Science of the Total Environment, 642, 2018, 864–878.

[23] Abdelhafez, A., Abass, M., Attea, T., environmental monitoring of heavy metals status and human health risk assessment in soil of Sahl El- Hessania area – Egypt. Polish Journal of Environmental Studuies, 2009, 24 (2), 459–467.

[24] Widziewicz, K., Kozłowska, W., Loska. K., Cancer risk from arsenic and chromium species bound to PM2.5 and PM1 – Polish case study. Atmospheric Pollution Research, 2016.

[25] Li, P., Kong, S., Geng, C., Han, B., Lu, B., Sun, R., …, Bai, Z. Assessing the hazardous risks of vehicle inspection workers' exposure to particulate heavy metals in their work places. Aerosol and Air Quality Research, 2013, 13, 255–265.

[26] Mulware, S., Trace elements and carcinogenicity: a subject in review. U.S. National Library of Medicine, 2013, 3, 85–96.

[27] US EPA New England Region. Index to EPA test methods. U.S. Environmental Protection Agency. New York, USA. 2003. [Online] Available from: https:// www.epa.gov/ [Accessed 25 June 2021].

[28] Melegy, A. El-Kammar, A. Yehia, M. Miro, G. Hydrogeochemical characteristics and assessment of water resources in Beni Suef Governorate, Egypt. Open Journal of Geology, 2014, 4, 44–57.

[29] Kenney, J. Alberta Government web site. 2021. [Online] Available from: https:// www.alberta.ca/index.aspx [Accessed 25 June 2021].

[30] The Arizona State Legislature. ADEQ the Arizona Department of Environmental Quality. 2021. [Online] Available from: https://azdeq.gov [Accessed 25 June 2021].

[31] New Zealand Government. New Zealand ambient air quality guidelines. 2021. [Online] Available from: https://www.mfe.govt.nz/air/air-guidance-and-wood-burners/ambient-air-quality-guidelines [Accessed 25 June 2021].

[32] Asakura, K. Inhalation risk assessment of trace elements emitted from coal-fired power plants. Environmental Science Research Laboratory, Japan, 2006, 368 (1), 397–402.

[33] Agency for Toxic Substances and Disease Registry. Public health statement sulfur dioxide (CAS:7446-09-5), 1998, 5285 Port Royal Road Springfield, VA 22161, [Online] Available from: https:// www.atsdr.cdc.gov/ [Accessed 25 June 2021].

[34] US EPA United States Environmental Protection Agency. Information quality act request for correction - Guidelines for carcinogen risk assessment, U.S. 2009. [Online] Available from: https:// www.epa.gov/ [Accessed 25 June 2021].

[35] Vimercati, L., Gatti, M., Gagliardi, T., Cuccaro, F., Maria, L., Caputi, A, …, Baldassarre, A. Environmental exposure to arsenic and chromium in an industrial area. Environmental Science and Pollution Research, 2017, 24, 11528–11535.

[36] Tavakoli, H., Azari, A., Ashrafi, K., Salimian, M., Momeni, M. Human health risk assessment of arsenic downstream of a steel plant in Isfahan, Iran: A case study. International Journal of Environmental Science and Technology, 2020, 17, 81–92.

[37] US EPA United States Environmental Protection Agency. Information quality act request for correction - Guidelines for carcinogen risk assessment, U.S. 2009. [Online] Available from: https:// www.epa.gov/ [Accessed 25 June 2021].