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Assessment of Radiation Hazards and Total Suspended Particulate of Cement Industry, Egypt

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Abstract

The most important naturally occurring radionuclides in cement industry arise from rocks and soils are the radioactive isotope of potassium (^{40}K) and the radionuclides from thorium (^{232}Th) and uranium (^{238}U) decay series. The knowledge of radioactivity in these materials is important to estimate the radiological hazards on human health. In addition to that, Suspended particles in the atmosphere are considered as one of the major pollution problems arises from cement production, especially, in greater Cairo; which is the main aim of this work.

By comparing the results of the activity of ^{238}U, ^{232}Th, and ^{40}K in the collected samples with the reported world median radioactivity levels it was found that; five samples in Turah factory have higher ^{238}U, ^{232}Th, and ^{40}K activity concentration values than the world median radioactivity levels, on the other hand in Helwan factory only the Bayrite sample has higher activity concentration value. Based on the radiological health hazard indices; there is some radiological threat to the workers in one factory (Tura), while the other factory (Helwan) is not

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posing any significant radiological threat to the workers. It`s worthy to mention that, nowadays Tura Factory was stopped. In addition to that, results from emissions impact of cement plant on ambient air quality around vicinity of Helwan factory revealed that the ground level concentrations of the Total Suspended Particulates (TSP) were well below the limits of the Egyptian and World Bank ambient air quality standards.

Keywords: Radiation hazard, Occupational radiation exposure, Total Suspended Particulate, AERMOD, Cement industry.

1. INTRODUCTION

The Cement Industry in Egypt is one of the oldest industries, the first cement plant was constructed in 1911, to be followed in 1927 by Egypt launching joint stock cement companies. Later, a large number of cement companies were launched and owned by the state, until the beginning of 1998, which was the start of the Private Sector Investments in the Cement Industry. At the moment there are 19 operating cement companies with 42 producing lines, which are geographically diversified in location across Egypt, (Bakr, 2019).

All building raw materials and products derived from rock and soil contain various amounts of mainly natural radionuclides of the uranium (^{238}U) and thorium (^{232}Th) series, and the radioactive isotope of potassium (^{40}K). In the ^{238}U series, the decay chain segment starting from radium (^{226}Ra) is radiologically the most important and, therefore, reference is often made to ^{226}Ra instead of ^{238}U, (UNSCEAR, 2008). The radioactive materials in raw and processed materials can be varying considerably depending on their geological source and geochemical characteristics. Thus, the knowledge of radioactivity in these materials is important to estimate the radiological hazards on human health. Furthermore, detailed knowledge of the radiological characteristics in cement allows better determination of the radiation exposure, both occupational and public, due to slag, fly ash, silica fume, kiln, car and truck tires used as raw materials during cement production. The workers at manufacturing sites are vulnerable to the cement or its raw materials exposure for a long time; hence, they spend nearly about 80% of their time indoor. Therefore, monitoring of radioactive materials in cement manufacturing is of primary importance from the view point of radiation protection in the environment. Several studies have been done for these purposes for several countries all over the world among them, recently, (Amrani and Tahtat 2001, Eissa et al 2004, El-Bahi 2004, Turhan 2008, Kobeissi et al 2008, and EL-Taher 2012).

In addition to that, one of the most critical impacts of cement manufacturing is the dust generated during transport, storage, milling, packing, etc. Atmospheric dust is an important source of air pollution particularly in dry climates, hence air pollution has potentially harmful or nuisance effects on human beings, animals, plants, their biological communities and habitats and on the soil which are found as total suspended particulates (TSP) or as dust fall. It has been reported that 1 kg of cement manufactured in Egypt, generates about 0.07 kg of dust in the atmosphere. Suspended particles in the atmosphere are considered as one of the major pollution problems arises from cement production in developing countries, especially in Egypt. The long and short term boundary values of each pollutant are determined based on Egypt environmental law No. 4/1994 **(**Egypt State of the Environment, Air Quality Report, 2010). The long-term boundary value that gives the maximum allowable annual arithmetic mean is 70 ($\mu g/m^3$) and short-term boundary value that gives the maximum daily arithmetic mean is 150 (24hours) ($\mu g/m^3$). While EPA standard value is 50 ($\mu g/m^3$) annually, (EPA, 2010).

There are two main factories in graeter Cario, Turha cement factory and Helwan Cement factory, and they are exisited in a residential areas, hence they might threat the population health as well as the worker inside the two factories, investigating the natural radioactivity (^{226}Ra, ^{232}Th and ^{40}K) in cement ore samples, some byproducts those factories would help in the evaluation of their possible radiological hazard indices as radium equivalent activity, absorbed dose rate, external and internal hazard index, gamma radiation hazard effect index and excess lifetime cancer risk for workers, which is the main aim of this work. Furthermore, the estimation of Total Suspended Particulate (TSP) dispersion patterns using ISCST3-AERMOD View model in Helwan factory that is emitted from the stacks of the cement industry and the determination of the area exposed by emission in which a health assessment might be threatened have been demarcated in this paper.

2. METHEDOLOGY

2.1 Sampling and Sample Preparation for Gamma Spectrometry

Sixteen samples of ore samples and some byproducts of the two cement factory in Cairo (Turah and Helwan) during the year 2018. Preparation of the collected samples for γ-ray measurements were carried out by drying the samples in an oven at a temperature of 105°C. The prepared samples were weighed, packed and sealed in polyethylene plastic container. Activity concentrations of ^{226}Ra (^{238}U series), ^{228}Ra (^{232}Th series), ^{40}K, in Bqkg^{-1} dry weight were measured using a gamma-ray spectrometer based on high purity germanium (HPGe) detector of 40% relative efficiency, 1.92 keV resolution for 1332 keV gamma-ray line of ^{60}Co. The minimum acquisition time was 80,000 s to reduce the statistical and area calculation errors (El-Mamoney and Khater, 2004), (Al-Trabulsy et al., 2011). The IAEA reference materials RGU-1 was used for the spectrometer efficiency calibration in the same geometry as that of the sample measurements, (IAEA, 1989). The samples were prepared at the Central Laboratory for Environmental Radioactivity Measurements, Inter-comparison and Training (CLERMIT), Nuclear and Radiological Regulatory Authority (NRRA) in Cairo, (Khater et al., 2005).

The gamma-ray lines at 295.2 keV and 351.9 keV from ^{214}Pb, and 609.3 keV, 1120.3 keV, and 1764.5 keV from ^{214}Bi were used to assess the ^{226}Ra activities. On the other hand, ^{232}Th activities were estimated using gamma-ray lines at and 583.19 keV from ^{208}Tl, 338.4 keV and 911.2 keV from ^{228}Ac, and 238.6 keV from ^{212}Pb, finally, the ^{40}K activity was determined at 1460.8 keV (single gamma line).

Radiological Effects estimation

1. Radium equivalent activity (Ra_{eq})

The distribution of ^{238}U, ^{232}Th and ^{40}K in the samples is not uniform. Uniformity with respect to exposure to radiation has been defined in terms of radium equivalent activity (Ra_{eq}) in BqKg^{-1} to compare the specific activity of material containing different amounts of ^{238}U, ^{232}Th and ^{40}K. This radium equivalent activity represents a weighted sum of activities of ^{40}K, ^{238}U and ^{232}Th radionuclides and is based on the estimation that 1 Bqkg^{-1} of ^{226}Ra, 0.7 Bqkg^{-1} of ^{232}Th, and 13Bq/kg of ^{40}K produce the same radiation dose rates. It is calculated from the following relation (Beretka and Mathew, 1985):

$$\mathbf{Ra_{eq} = C_{Ra} + 1.43 C_{Th} + 0.077\ C_K} \qquad (1)$$

Where, C_{Ra}, C_{Th} and C_K are the radioactivity concentration in $Bqkg^{-1}$ of ^{238}U, ^{232}Th, and ^{40}K, respectively.

2. Dose rate calculation

The absorbed dose rate was calculated from the measured activities of ^{238}U, ^{232}Th and ^{40}K in using the formula of (Papastefanou et al 2005):

$$\mathbf{D(nGyh^{-1}) = 0.462 C_u + 0.604 C_{Th} + 0.042 C_K} \qquad (2)$$

Where D, is the absorbed dose rate ($nGyh^{-1}$), C_U, C_{Th} and C_K are the activity concentrations ($Bqkg^{-1}$) of ^{238}U, ^{232}Th and ^{40}K, respectively. To estimate the annual effective dose rates, the conversion coefficient from absorbed dose to effective dose, 0.7 $SvGy^{-1}$ and outdoor occupancy factor of 0.2 proposed by (UNSCEAR, 2000) were used.

3. Annual effective dose equivalent (AEDE)

The annual effective dose (Svy^{-1}) was calculated by the formula of (Ramasamy, et al., 2010):

$$\mathbf{AEDE(outdoor)(mSvy^{-1}) = D(nGyh^{-1}) * 8760h * 0.2 * 0.7 SvGy^{-1} * 10^{-3}} \qquad (3)$$

Where, 0.2 is the occupancy factor for outdoor, 8760 is the total time of the year in hours and 0.7 $SvGy^{-1}$ is the conversion factor for external gamma irradiation.

4. External hazard index (H_{ex}) and internal hazard index (H_{in})

The external hazard index (H_{ex}) represents the external radiation exposure associated with gamma irradiation from radionuclides of concern. The value of H_{ex} should not exceed the maximum acceptable value of one in order to keep the hazard insignificant. The external hazard index (H_{ex}) and internal hazard index (H_{in}) were defined by equations (4) and (5) (Beretka & Mathew, 1985; OECD, 1979).

$$\mathbf{Hex = C_U/370 + C_{Th}/259 + C_K/4180 \leq 1} \qquad (4)$$

$$\mathbf{H_{in} = C_{Ra}/185 + C_{Th}/259 + C_K/4180 \leq 1} \qquad (5)$$

5. Representative level index (Iγ)

It is used to estimate the gamma radiation hazard associated with the natural radionuclide in specific investigated samples According to RP 112 (EC, 1999). It is given by the equation:

$$\mathbf{I\Upsilon = C_{Ra}/150 + C_{Th}/100 + C_K/1500} \qquad (6)$$

Where, C_{Ra}, C_{Th} and C_K are the radioactivity concentrations in $Bqkg^{-1}$ of ^{238}U, ^{232}Th, and ^{40}K.

6. Excess lifetime cancer risk (ELCR)

ELCR defined as the excess probability of developing cancer at a lifetime due to exposure level of human to radiation. (ICRP-60, 1990): Excess lifetime cancer risk (ELCR) calculated using the following formula:

$$\mathbf{ELCR = AED * DL\ (40y) * Rf\ (0.5\ SV^{-1})} \qquad \mathbf{(7)}$$

Where, AED, DL and RF are the annual effective dose equivalent, duration of life (40y) and risk factor (Sv^{-1}), fatal cancer risk per Sievert.

Quality control assurance

The quality control was provided by using certified reference materials sediment samples (IAEA, Vienna) for NAA.

2.2 Impact Assessment of Ambient Air Quality

The Helwan cement plant was established in 1929 It is located 30 Km south of Cairo on an area of 1.000.000 m^2 with 10 production lines (8 in operation) for eight production lines with total production of 4.00934 million tons.

Dispersion modeling

The dispersion modeling of air pollutants from Helwan cement facility has been conducted using ISCST3- AERMOD View Gaussian plume dispersion model. The model was employed in the study to simulate the dispersion of air of the Total Suspended Particulates (TSP) emitted from the stacks of the plant to predict ground-level concentrations across a gridded domain at 24-Hr and annual averaging time ground level concentration (GLC) influenced by emissions from the kiln, Clinker cooler and cement mill stacks, using source characteristics, emission rates, meteorological data and topography of the interest area as input parameters. ISCST3- AERMOD View uses mathematical equations, which describe the atmosphere, dispersion, chemical and physical processes within the plume, to calculate concentrations at various locations.

Input data required by the model

Simulations have been performed over a period of one year (2017) with the time series of meteorological data provided by the Helwan station. One of the requirements of ISCST3- AERMOD View Source is the input data about the sources of emissions and receptor status. Pathway was considered as a point source. The stack characteristics as stack height, stack diameter, stack exit velocity and emission rates of cement stacks, also the temperature and velocity of the pollutant exiting the stack .By using source characteristics, emission rates and meteorological data as input data to the model, dispersion modeling was carried out in an flat terrain area of 20 km x 20 km extent , as shown in figure (2.1) , and Uniform Polar Grid Receptor Network with 36 Direction (360 receptors, with Urban dispersion coefficient). Figure (2.1) illustrates the wind rose of meteorological data used for the year 2017.

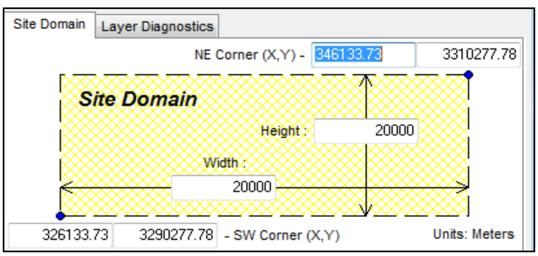

Fig. (2.1) Site domain of the modeled area.

3. RESULTS AND DISCUSSION

3.1 Radioactivity Measurements

The specific activities of the naturally occurring radionuclides (^{226}Ra, ^{232}Th, and ^{40}K) of 16 primary (raw) materials samples, which are used in the cement production industry, in Helwan and Turah factories are presented in Table (3-1) and their statistical analyses are shown in Table (3-2).

Table (3-1): Activity concentrations (Bqkg^{-1}) in ore samples and some byproducts of some cement factories

Factory	Sample No	Sample Type	^{226}Ra	^{232}Th	^{40}K
Turah	1	Soil from storage zone	258.45±4.97	230.34±8.10	2748.69±48.88
	2	Mixed Clay	18.95±1.25	24.04±2.29	309.36±15.47
	3	Sand	8.80±0.77	8.60±1.45	131.64±8.53
	4	Bayrite	21.88±1.15	16.61±2.26	153.29±9.75
	5	Baybass	26.01±1.81	6.13±1.04	1953.87±52.17

	6	**Galkh**	447.92±6.11	33.86±2.83	125.75±8.49
	7	**Gypsum**	34.34±1.75	10.59±1.37	122.28±8.72
	8	**Yellow clay**	25.91±1.58	43.81±2.56	250.43±14.21
	9	**Rock**	36.00±1.84	5.33±1.15	16.88±1.83
	10	**Black clay**	29.59±1.76	43.55±4.25	272.19±15.25
	11	**Clinker**	23.10±1.25	5.17±0.93	36.10±3.34
Helwan	12	**Sand**	6.42±0.59	7.05±1.45	146.12±9.06
	13	**Gypsum**	17.08±1.25	4.23±0.99	38.97±3.75
	14	**Clay**	19.33±1.48	20.58±2.24	315.63±17.66
	15	**Bayrite**	83.48±3.14	10.66±1.69	146.12±10.75
	16	**Rock**	29.17±1.89	5.04±1.25	18.18±1.99

Table (3-2): Some statistical analysis of the samples

Item	Mean	Standard Deviation	Kurtosis	Skewness	Minimum	Maximum
Turah						
^{226}R	84.63	139.57	4.75	2.30	8.80	447.92
^{232}Th	38.91	65.19	9.52	3.02	5.17	230.34
^{40}K	556.41	909.57	3.12	2.05	16.88	2748.69
Helwan						
^{226}R	31.10	30.38	3.68	1.85	6.42	83.48
^{232}Th	9.51	6.67	2.26	1.55	4.23	20.58
^{40}K	133.00	118.03	0.79	0.95	18.18	315.63

The activity of ^{226}Ra, ^{232}Th, and ^{40}K in the collected samples from Turah Factory ranged from 8.8 to 447.92 Bq/kg, 4.23 to 20.58 Bq/kg, and 16.88 – 2748.69 Bq/kg, respectively. On the other hand, their activity in the collected samples from Helwan factory ranged from 6.42 to 83.48 Bq/ kg, 5.17 – 230.34 Bq/kg, 16.88 – 2748.69 Bq/kg, respectively.

Comparing the previous results with the reported world median radioactivity levels for ^{226}Ra, ^{232}Th, ^{40}K (35, 30, and 400 Bq /kg, respectively) **(UNSCEAR, 2000)**; it was found that; two samples in Turah factory have higher ^{226}Ra, ^{232}Th, and ^{40}K activity concentration values than the world median radioactivity levels (Soil from storage zone and Galkh samples). Two clay samples (Yellow and Black ones) have a higher ^{232}Th activity concentration values than the world median radioactivity levels on the other hand Baybass sample has a higher ^{40}K activity concentration values than the world median radioactivity levels. Furthermore, the comparison of ^{226}Ra, ^{232}Th, and ^{40}K activity concentration values in Helwan factory; revealed that only the Bayrite sample has higher ^{226}Ra activity concentration value than the world median radioactivity levels.

From the inspection of Table (3-2), it is clear that the skweness and Kurtosis of Helwan samples are less than that of Turah samples revealing the asymmetric distribution in Turah samples than in Helwan and this may be attributed to the diversity of textures and formations of the samples.

Table (3-3) show a moderate linear correlation coefficient of 0.75 between ^{232}Th and ^{40}K levels which might be attributed to the fact that the industrial activities such as mining processes concentrate and redistribute ^{232}Th and ^{40}K in the environment.

Table (3-3): Correlation coefficient between radioelements in the collected samples

Radioelement	^{226}R	^{232}Th	^{40}K
^{226}R	1		
^{232}Th	0.47	1	
^{40}K	0.26	0.75	1

Radiological Hazard Indices

The radiological hazards indices: radium equivalent activity (Raeq), absorbed dose rates (D), annual effective dose (AED), external and internal hazard indices (H_{ex} and H_{in}), the representative level index (I_γ) and excess lifetime cancer risk (ELCR) were calculated for collected samples are given in Table (3-4).

Table (3-4): Radiological Hazards Indices for ore, byproduct and cement samples collected from two Egyptian factories

Sampling Type	Raeq	D	AED	H_{in}	H_{ex}	I_{yr}	ELCR
Turah Factory							
1	799.48	373.97	458.64	2.86	2.16	5.86	9172.79
2	77.14	36.26	44.48	0.26	0.21	0.57	889.50
3	31.23	14.79	18.14	0.11	0.08	0.23	362.70
4	57.45	26.58	32.60	0.21	0.16	0.41	652.04
5	185.23	97.78	119.92	0.57	0.50	1.54	2398.46
6	506.02	232.67	285.35	2.58	1.37	3.41	5706.92
7	58.90	27.40	33.60	0.25	0.16	0.42	672.02
8	107.84	48.95	60.03	0.36	0.29	0.78	1200.66
9	44.91	20.56	25.21	0.22	0.12	0.30	504.22
10	112.83	51.41	63.05	0.38	0.30	0.81	1260.95
11	33.26	15.31	18.77	0.15	0.09	0.23	375.46
Helwan Factory							
12	27.76	13.36	16.39	0.09	0.07	0.21	327.76
13	26.12	12.08	14.81	0.12	0.07	0.18	296.27
14	73.07	34.62	42.46	0.25	0.20	0.55	849.20
15	109.98	51.15	62.73	0.52	0.30	0.76	1254.54
16	37.77	17.28	21.20	0.18	0.10	0.26	423.91

1. Radium equivalent (Ra_{eq})

The obtained values of Ra_{eq} (Table 4) in Turah factory ranged from 31.23 Bq/ kg to 799.48 Bq / kg with a mean of 138.12 Bq / kg. The minimum and maximum values are due to the sand sample no 3 and the soil sample from the storage zone sample no 1, respectively. Only two samples exceeding the permissible limit of 370 Bq / kg, (OECD, 1979), those samples are that one collected from the storage zone and the other is the Galkh samples (used in oven for heating). On the other hand, the calculated values of Ra_{eq} (Table 4) in Helwan factory ranged from 26.12 Bq/ kg to 109.98 Bq / kg with a mean of 54.94 Bq / kg.

Based on the previous discussion, it is obvious that there is a significant radiological threat to the workers, while Helwan factory is not posing any significant radiological threat to the workers.

2. Dose rate calculation

The obtained values are presented in Table (3-4) and range from 14.79 nGy /h to 373.97 nGy/ h with a mean of 85.97 nGy /h. Nearly eight samples in Turah samples are higher in their dose rate than the dose rate in air outdoors gamma rays in normal circumstances, 57 nGy/ h (UNSCEAR, 2000). On the other hand, only two samples exceeding this value.

3. Annual effective dose equivalent (AEDE)

The calculated values of the annual effective dose rates of Turah factory samples ranged from 18.14 μSv /y to 458.64 μSv/y with mean value of 105.44 μSv/y, and in Helwan factory it ranged from 14.81 μSv /y to 62.73 μSv/y with mean value of 31.52 μSv/y. The annual effective dose equivalent in Turah factory exceeding the worldwide average outdoor annual effective dose (70 μSv/y), (**Örgun** et al., 2007) those samples are (the soil sample from storage zone sample no1, Baybass sample no 5, Galkh sample no 6). On the contrary all samples in Helwan Factory did not exceed the worldwide average outdoor annual effective dose.

4. External hazard index (H_{ex}) and internal hazard index (H_{in})

With respect to the fact, that the prime objective of these indices is to limit the radiation dose to a dose equivalent limit of 1 mSv/ year, Beretka and Mathew (1985); and from the inspection of the calculated H_{ex} and H_{in} indices (Table3-4). In Turah factory those two indices ranged from 0.11 to 2.86 and 0.08 to 2.16 with a mean value of 0.23 and 0.25, respectively (this mean value is not exceeding the unity). While in Helwan factory; all samples did not exceed the unity.

5. Representative level index (Iγ)

The **Iγ** is correlated with the annual dose rate due to the excess external gamma radiation caused by superficial material and this index can be used as screening tool for the identifying materials that might be of higher dose rates, (Ravisankar et al., 2012). Values of **Iγ** ≤ 2 correspond to a dose rate criterion of 0.3 mSv year/1, whereas **Iγ** ≤ 6 corresponds to a criterion of 1 mSv year/1 (EC, 1999). All samples in Helwan factory and all samples in Turah factory are less than 2, except three samples in Turah factory (sample from the storage zone, bay bass sample and Galkh sample).

6. Excess lifetime cancer risk (ELCR)

In Turah factory ELCR ranged from 362.7 to 9172.79 with a mean value of 2108.7, on the other hand, in Helwan factory it ranged from 296.27 to 1254.54 with a mean value of 630.34.

3.2 Ambient air quality around Helwan cement vicinity

In this study we assessed the impacts of criteria air emissions from cement plants on ambient air quality by the determination of the ground level concentrations of (TSP) using the ISCST3-AERMOD view atmospheric dispersion model over 1-hr, 24-h, and annual averaging periods and comparing the results with the emission standards of World Bank and Egyptian ambient air quality standard.

Analysis of Meteorological data

To estimate the air pollutant levels, the ISCST-3 AERMOD View model incorporates different factors related to the emission source and meteorological parameters. The required hourly meteorological data, as inputs for the modeling were obtained from the nearest Egyptian meteorological station close to the cement plant for the whole year 2017. Surface wind speeds and wind directions at 10 m above ground level were used in the meteorological analysis (WR plot software, https://www.weblakes.com/). The analysis result of wind rose (fig. 3.1) of the surface and profile wind shows that the wind tends to head from the North North East (NNE) with a mean velocity of 3.51 m/sec and a calm winds frequency of 2.81%.

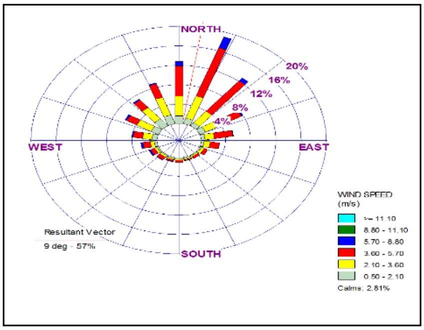

Fig (3.1) Wind Rose for the study area .

Ground level concentrations of (TSP) and Air Quality impact

ISCST-3 AERMOD View model has been used in this study. The model is an advanced Gaussian dispersion model approved by the United States Environment Protection Agency (USEPA) for use in regulatory assessments undertaken within the United States. It is one of the most widely used regulatory models in the world. Ambient Air Quality Data Introduction Concentrations of ambient pollutants vary according to both time and location. They are affected by many factors, the most significant being the size, number and location of emission sources and the prevailing weather. Total suspended particulates matters become significant emissions of concern.

Predicted ground level concentrations

The distribution of total suspended particulates (TSP) from all stacks of Helwan Cement Company for the averaging period of 24 hours and one year was simulated using ISCST3- AERMOD View. Graphical output for the model is presented in figures (3-1,3-2). Figure (3-3) represents the impact tool for the annual statistical evaluation. Table (3-5) shows the results of the model runs for the cement manufacturing facility, and their comparisons with the Significant Impact concentrations and the ambient air quality standards.

It is clear that predicted Total Suspended particulates (TSP) concentration for All group sources for the 24-hrs and annual TSP concentration are in compliance with Egyptian Environmental affairs Agency EEAA, “Environmental Impact Assessment guidelines for cement manufacturing plants”, as the Egyptian Standard of ambient air **Ministry of State for Environmental Affairs, 2009** and World Health Organization (WHO) (WHO, 2005 and WHO, 2017) Figures (3-

2, and 3-3) show the pollutant contour plot-files for TSP. Figure (3-4) shows the plot of annual concentration values for source Group is represented with distance.

The plot files show the most impacted areas based on the predicted pollutant concentrations generated by the model runs. The color coded scale in the figures indicates the various impact concentrations obtained up to the predicted maximum concentrations achieved.

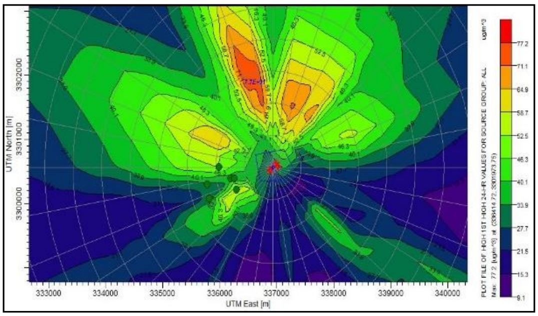

Fig (3-2): Dispersion of total suspended particulates (TSP) for 24-hr average

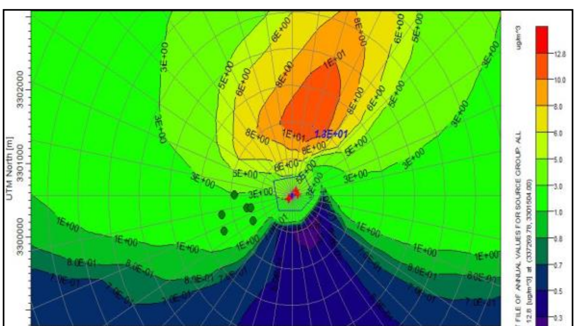

Fig (3-3): Dispersion of total suspended particulates (TSP) for annual statistical period

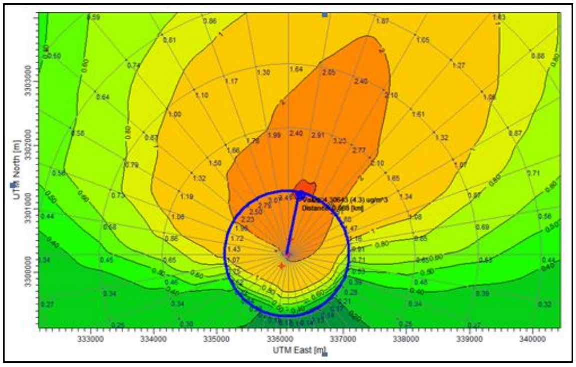

Fig (3-4): Impact tool: value is 12.8 μg/m³, distance: 0.985 Km

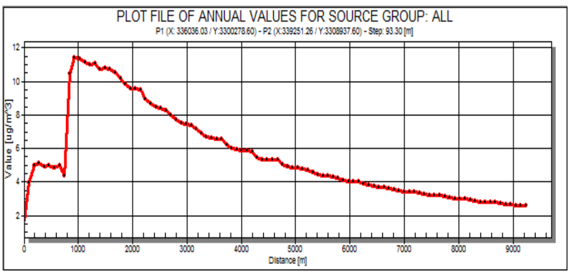

Fig (3-5) TSP annual concentrations VS. distance around the cement plant

Table (3-5): TSP – Concentration- Source Group: ALL STACKS

Averaging period	Egyptian Standards	WHO Guidelines	Max Conc. (μg/m³)	X(m)	Y(m)
24-Hr	300	230	7.72E+01	336414.72	3301973.76
Annual	90	80	1.28E+01	337269.78	3301504. 00

The output of the model predicted that the maximum environmental concentration of TSP for 24 hours and annual periods was 77.2 (μg/m³) and 12.8 (μg/m³) respectively, which is below the Egyptian and WHO ambient air quality standards.

Comparison with Egyptian Threshold Limit Values (TLVs) (as stipulated in Law 4/1994 and Law 9/2009) show that the concentrations of gaseous pollutants in ambient air at the proposed site are below the TLVs for 24- hour and annual averages.

According to the AERMOD view model, TSP emission from all stacks of Helwan cement industry tends to move toward the East. Helwan cement established prior issuance of the Executive Regulation of Environment Law - before 1995, then the maximum allowed limits for the factory 300 mg /m^3. Results showed that the emission concentrations of the cement plant were found to be less than the limits of the Egyptian and World Bank ambient air quality standards and have no impact on health in nearby communities.

CONCLUSION

The activity levels of the natural terrestrial radionuclides of ^{226}Ra, ^{232}Th, and ^{40}K were measured using a gamma-ray spectrometry system for the raw material samples in both Turah and Helwan factories in Egypt. Different hazard indices as Ra_{eq}, H_{ex} and H_{in}, AEDE (outdoor), Iγ, and ELCR were calculated to assess the radiological hazard of the collected samples on the workers in these factories. Based on these finding it was concluded that Based on the previous discussion, it is obvious that there is a significant radiological threat to the workers, while Helwan factory is not posing any significant radiological threat to the workers. Finally Cement Industry in Egypt is an important source of air pollution, their diffusive emissions have been estimated to be normally at low levels above the surface, and will also be trapped during specific meteorological conditions in the cold and stable air giving rise to high concentrations. According to the above results the emission concentrations of the cement plant were found to be less than the limits of the Egyptian and World Bank ambient air quality standards. The contribution of the cement industry to total suspended dust ambient levels is small.

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Declarations

Code availability: the used code is available at: WR plot software, **https://www.weblakes.com.**

Conflict of interest: The authors declare that there are no competing interests.

Availability of data and materials: All data generated or analyzed during this study are included in this manuscript.

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