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Contour maps of Air Pollutants and their Health Risk Assessment in Abu-Rawash Wastewater Treatment Plant, Egypt

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Abstract

The current study was conducted to study air pollutants emitted in WWTP, as well as to assess the exposure levels of pollutants and their health risks to workers and nearby residents using a modeling method for United States Environmental Protection Agency (US EPA). Outdoor concentrations of CO, H_2S, NH3, SO_2, NO_2, TVOCs, PM_1, $PM_{2.5}$, PM_{10}, and TSP were detected in 30 sites inside Abu-Rawash wastewater treatment plant, Egypt. Concentration distributions of air pollutants were plotted on contour maps using Software Surfer 13.

The results showed that concentration levels of all pollutants were below the permissible thresholds limits set by the Egyptian Environmental Law No. 4 of 1994. Concentration distributions of gaseous pollutants and particulate matter show two hotspots in Abu-Rawash WWTP identified at the northwest of the plant. Non-carcinogenic risks were evaluated and the results showed that the hazard quotient (HQ) was less than 1 for all air pollutants, except H_2S and TVOCs. This indicates that there is adverse chronic health effects occurred due to H_2S, and TVOCs exposure. In addition, Hazard index (HI) of pollutants was (57.3) greater than 1; indicating that there is adverse chronic health effects could be induced by exposure to pollutants in Abu-Rawash WWTP. Furthermore, carcinogenic risk of TVOCs was evaluated as lifetime cancer risk (LCR) which was (0.0513) greater than 10-4; indicating a high risk of developing cancer for exposed person.

Keywords: Wastewater treatment plant (WWTP); Air pollutant; contour maps; and Risk assessment

1. Introduction

Air Pollution from Industrial sources is one of the most important environmental challenges in many countries. Wastewater treatment units are one of these sources that commonly contribute several problems of air emissions related to their processes [1-2]. Wastewater treatment plants (WWTP) are regarded as a significant source of aerosols and may pose serious health risks to both workers and residents in surrounding areas [3-4]. A number of atmospheric factors such as temperature, wind speed, wind direction, precipitation, and relative humidity influence the aerosol spread as well as the ability of microorganisms to survive in the air [5]. In urban areas, emissions from WWTP depend on the nature of wastewater, water transmission system, operational characteristics of the treatment plant and the weather conditions [6-7].

Various types of contaminants are released into the atmosphere during the processes and treatment of wastewater that can pollute the environment in many ways [7-8]. Prominent air pollutants formed during wastewater treatment processes include: particulate matter (PM), carbon monoxide (CO), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), ammonia (NH_3), hydrogen sulfide (H_2S), Volatile Organic Compounds (VOCs) as well as odor problem [9-14]. In addition, if the location of wastewater treatment plant is near main roads, particulate matter and other pollutants, such as CO, SO_2, NO_2, will most likely be increased in its air surrounding [15-16].

The most important sources of odors in WWTP are sludge thickening processes, sludge digestion units and sludge load-out systems [7, 17]. During the

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recent years, it has seen a rise in the frequency of public odor complaints due to residential areas' rapid growth and its burden on wastewater treatment plants (WWTPs), and increased public demand for various privatized water companies [7].

Air quality and the extent of its pollution (physical, chemical and biological) greatly affect the health and life of humans, animals or plants exposed to it [5, 18-19]. Waste management facilities produce atmospheric emissions that could be harmful to human health. The potential health hazards related to WWTP aerosols are documented commonly for occupational exposure [5, 20]. Effects, including respiratory and gastrointestinal symptoms, have been reported in workers exposed to particulate matter and aerosols [21]. Similar health problems may occur in people who live near these WWTP plants and who may be exposed to these emissions.

Particulate matter (PM) is one of the significant pollutants with adverse health impacts such as lung and cardiovascular diseases and premature mortality [13-14, 22]. Particulate matter has the ability to reach the bloodstream as well as the lungs. It may also worsen asthma, decrease lung function, cause emphysema or chronic bronchitis to develop, cause irregular heartbeats, and result in nonfatal heart attacks [23]. Many of VOCs have been identified to be human carcinogens so there is growing concern for them [24].

The health effects of carbon monoxide are more serious for those suffering from cardiovascular disease, however even healthy individuals are susceptible to these effects. "High concentrations of carbon monoxide affect the body's ability to deliver oxygen to the b[7]n and organs, consequently, the central nervous system, including visual tracking, learning ability, and dexterity can thus be affected. Carbon monoxide also exacerbates asthma, and can even cause death at very high concentrations" [10, 25]. Health effects due to low concentrations of nitrogen dioxide include eye, nose, throat, and lung irritation, as well as shortness of breath and tiredness. On the other hand, "inhaling air with high NO_2 concentrations can cause damage of the respiratory tract, a buildup of fluid in the lungs, reduced oxygenation of tissues, and possibly death" [26]. The health effects of exposure to high levels of sulfur dioxide include breathing difficulties and burning of the nose and throat [23, 26-27]. Ammonia and Hydrogen sulfide have peculiar smell and can constitute sources of olfactory nuisance [28]. "Hydrogen sulfide is also toxic to humans and environment" [16, 29]. Its health effects can vary depending on the level and duration of exposure. High concentrations of hydrogen sulfide can cause shock, convulsions, inability to breathe, extremely rapid unconsciousness, coma and death [30].

A contour line is a function with two variables that unites points of equal value along a curve where the function's value is constant *[31]*. A contour line, known as a "contour", connects locations with the same elevation (height) above a predetermined level, like mean sea level [32]. A contour map is a map illustrated with contour lines; the contour interval of a contour map is the difference in elevation between successive contour lines *[33]*. Contour maps are particularly helpful for diffuse pollution types or scales. Maps depicting air pollution contamination are among of the most often used environmental science contour applications *[34]*.

To guide the implementation of waste management policies, decision-makers need information about the potential effects of WWTP emissions on public health. Therefore, the current study aimed to :i) investigate the air pollution profiles in Abu-Rawash WWTP, in Egypt, and evaluate the exposure level of workers and residents near a wastewater treatment plant to air pollutants. ; ii) to plot the concentration distributions of pollutants (CO, SO_2, NO_2, NH_3, H_2S, VOC_S, PM_1, $PM_{2.5}$, PM_{10}, and TSP) to illustrate the hot spots using Surfer 13 program; iii); In additions, iv) estimate the health risks of such pollutants to workers and residents nearby the wastewater treatment plant using method from US Environmental Protection Agency [35]. The present study could provide a basis for improving the air quality in wastewater treatment plants in order to control the health risks.

2. Materials and Methods

2.1. Description of Study Area

In 2017, the Egyptian Ministry of Housing, Utilities and Urban Development (MHUUD) authorized a company (Orasqualia) to expand, operate and maintain Abu Rawash Wastewater Treatment Plant (WWTP) in Cairo, Egypt [36]. Abu Rawash WWTP is located northwest of Greater Cairo (as shown in Figure 1), Where the raw sewage is collected from Greater Cairo. It provides primary and secondary treatment for industrial and domestic wastewater. Abu Rawash WWTP was designed to treat an average flow of 1.2 - 1.6 million m3/day, where the treated wastewater is discharged into a linear channel and then to Al-Rahawi drain. It serves 6 million people, making it one of the largest plants in the world [36-37]. The general conditions of the Abu Rawash area are summarized in Table 1.

Table 1
General Conditions for Abu Rawash Study area

Hydrogeological and hydraulic Criteria		Site Criteria	
Lithology of aquifer	Homogeneous	Treatment	Primary and secondary
Recharge site availability	Available	vulnerability	Medium - Low
Accessibility	Easy	Soil classification	Sand
Distance from treatment plant	200 m	Depth to water table	3.5 m
Distance from drinking water plants	Faraway	Transmissivity	300 m^2/day
Land availability	Available	Land use	Agricultural

Source: [37].

2.2. Data Collection

Prominent air pollutants (CO, SO_2, NO_2, NH_3, H_2S, VOC, PM_1, $PM_{2.5}$, PM_{10}, and TSP) were monitored at 30 sites in Abu Rawash WWTP during 2020. The gaseous pollutants were monitored using Aeroqual 500, portable air quality monitors, while CEL-712 Micro-dust Pro, Casella CEL was used for particulate monitoring.

2.3. Distribution of Data

Software Surfer 13 was applied on data collected to plot contour maps of air pollutants (CO, SO_2, NO_2, NH_3, H_2S, VOC, PM_1, $PM_{2.5}$, PM_{10}, and TSP) concentration levels in Abu-Rawash WWTP.

2.4. Wind Rose Plots for Meteorological Data (WRPLOT View)

Wind-Rose version 4.41 was used to plot meteorological data (WRPLOT View) for Abu-Rawash WWTP. It provides visual wind rose plots and wind speed classes for a given location and time period [38].

2.5. Health Risk Assessment

Health risk assessment is interested with pollutant`s chronic effects (non-carcinogenic or carcinogenic) rather than acute effects [16, 39]. Equation (Eq. 1A) is used to calculate chronic daily intake (CDI, mg/kg.day) [35]:

$$\mathbf{CDI = (C \times IR \times EF \times ED)/ (BW \times AT)} \quad \textbf{(Eq. 1A)}$$

Non-carcinogenic risk is expressed as hazard quotient (HQ, dimensionless), which is calculated by using reference dose (RfD) (mg/kg.day) as shown in equation (Eq. 1B). Hazard index (HI, dimensionless) is sum of hazard quotient according to equation (Eq. 1C) [35]. US EPA (2017) [35] mentioned that: if HI < 1, this indicates no health effects due to exposure to pollutants; if HI > 1, indicates that chronic adverse health effects have occurred due to exposure to pollutants.

$$\mathbf{HQ = CDI / RfD} \quad \textbf{(Eq. 1B)}$$

$$\mathbf{HI = \sum HQ} \quad \textbf{(Eq. 1C)}$$

$$\mathbf{RfD = ((RFC \times IR)/BW)} \quad \textbf{(Eq. 1D)}$$

Where: RFC (mg/m^3) is reference concentration and it is provided by US EPA (2017) [35], IR (m^3/day) is the daily inhalation rate estimated based on the daily activity pattern that was used in [40-42].

Cancer slope factor (CSF, mg/kg.day $^{-1}$) is used to calculate the lifetime cancer risk (LCR, dimensionless) as shown in equation (Eq. 1D) [35, 43]:

$$\mathbf{LCR = CDI \times CSF} \quad \textbf{(Eq. 1D)}$$

US EPA (2017) [35] mentioned that: if LCR < 10^{-6}, indicates that there is no cancer risk; if $10^{-6} \leq$ LCR < 10^{-4}, indicates portability for moderate cancer risk; if LCR > 10^{-4}, indicates there is portability for high cancer risk. Parameters used in above equation are summarized in Table 2.

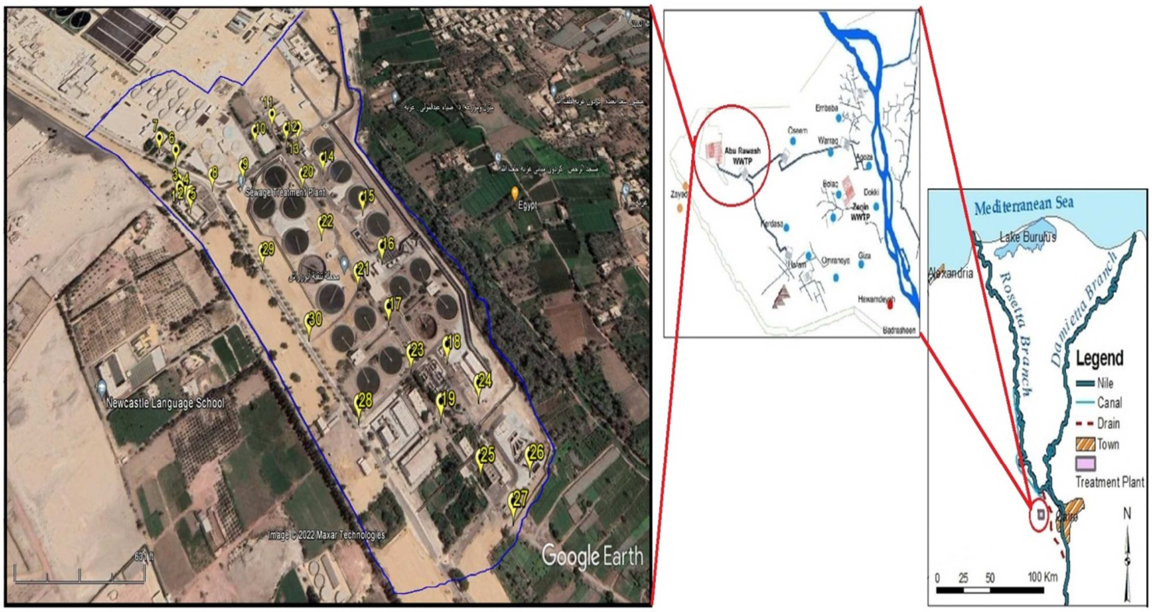

Figure 1: Abu-Rawash WWTP Location and the Monitoring Sites

Table 2
The exposure assessment factors

Variable	Description	Value	Unit
C [16]	Concentration	The current study	mg/m^3
IR [16]	Inhalation Rate	20	m^3/day
EF [16]	Exposure Frequency	365	Day/year
ED [16]	Exposure Duration	30	year
BW [16]	Body Weight	70	kg
AT [16]	Average Lifetime: - Carcinogenic - Non-carcinogenic	25550 365 × ED	day
RfD	Reference Dose	SO_2: 0.148 [44] NO_2: 0.01 [45] NH_3: 0.277 [46] CO: 11.4 [47] H_2S: 0.02 [48] VOCs: 8.55E-02 [49] $PM_{2.5}$:0.05323 [50] PM_{10}: 0.142 [51] TSP: 0.1714 [52]	mg/kg.day
CSF	Cancer Slope Factors	VOCs: 2.91E-02 [7]	$(mg/kg.day)^{-1}$

3. Results and Discussions

3.1. Concentration Levels of Air Pollutants

Table 3 shows the average levels of air pollutant concentrations at 30 sites in Abu-Rawash WWTP. The concentration levels of gaseous pollutants were in the range 0.10 - 9.40, 0.10 - 0.85, 0.018 - 0.059, 0.19 - 1.00, 0.04 - 1.31 and 7.6 - 28.1 mg/m^3 for CO, SO_2, NO_2, NH_3, H_2S and VOC, respectively. While the concentration levels of particles were in the range 0.024 - 0.178, 0.088 - 0.228, 0.088 - 0.389, and 0.168 - 0.483 mg/m^3 for PM_1, $PM_{2.5}$, PM_{10}, and TSP, respectively. The results showed that all concentration levels are below the permissible thresholds in Labor Law No. 12 of 2003 and Environmental Protection Law No. 4 of 1994 and its executive regulations amended by Cabinet Resolution 1095 of 2011 in the Arab Republic of Egypt [53].

Table 3
Air Pollutants concentration Levels in Abu-Rawash WWTP

Sites	Coordinates		Mean concentration levels (mg/m^3)									
	Latitude	Longitude	CO	SO_2	NO_2	NH_3	H_2S	VOC	PM_1	$PM_{2.5}$	PM_{10}	TSP
1	30.066193°	31.072061°	0.10	0.44	0.041	0.30	0.27	17.9	0.105	0.166	0.258	0.336
2	30.066247°	31.071894°	0.10	0.42	0.044	0.26	0.04	28.1	0.087	0.121	0.221	0.285
3	30.066113°	31.071956°	0.10	0.35	0.043	0.19	0.14	12.5	0.166	0.193	0.246	0.314
4	30.066033°	31.072223°	1.49	0.59	0.038	0.31	0.30	26.2	0.162	0.184	0.227	0.319
5	30.065950°	31.072236°	1.18	0.26	0.026	0.30	0.35	17.7	0.051	0.092	0.088	0.168
6	30.066882°	31.071704°	0.65	0.11	0.059	0.22	0.21	12.1	0.101	0.167	0.211	0.281
7	30.067167°	31.071295°	0.89	0.37	0.049	1.00	1.31	14.9	0.178	0.226	0.352	0.414
8	30.066358°	31.072667°	1.53	0.40	0.048	0.80	0.55	10.3	0.129	0.182	0.218	0.315
9	30.066565°	31.073351°	0.97	0.85	0.044	0.60	0.38	13.6	0.171	0.215	0.298	0.473
10	30.067313°	31.073565°	0.77	0.56	0.032	0.40	0.55	8.6	0.172	0.228	0.333	0.483
11	30.067678°	31.073956°	0.44	0.39	0.041	0.40	0.34	15.1	0.146	0.191	0.389	0.429
12	30.067352°	31.074338°	0.35	0.63	0.036	0.32	0.46	9.2	0.094	0.139	0.151	0.275
13	30.067383°	31.074613°	9.35	0.51	0.044	0.50	0.25	16.1	0.13	0.142	0.159	0.273
14	30.066721°	31.075242°	0.57	0.49	0.032	0.50	0.29	8.3	0.107	0.119	0.144	0.289
15	30.065948°	31.076153°	1.58	0.31	0.031	0.30	0.38	12.2	0.11	0.132	0.147	0.288
16	30.065097°	31.076529°	9.40	0.71	0.041	0.30	0.33	9.6	0.024	0.115	0.260	0.331
17	30.064138°	31.076592°	4.90	0.74	0.032	0.24	0.22	11.3	0.088	0.112	0.148	0.228
18	30.063599°	31.077691°	1.10	0.57	0.029	0.20	0.35	7.6	0.071	0.103	0.101	0.223
19	30.062850°	31.077455°	0.59	0.67	0.023	0.19	0.16	14.5	0.065	0.118	0.122	0.291
20	30.066408°	31.074770°	4.40	0.43	0.022	0.20	0.23	12.8	0.113	0.144	0.173	0.376
21	30.064685°	31.075989°	2.40	0.17	0.039	0.21	0.27	11.9	0.113	0.157	0.204	0.301
22	30.065496°	31.075218°	1.40	0.28	0.027	0.40	0.22	9.5	0.039	0.090	0.123	0.178
23	30.063483°	31.076971°	0.83	0.10	0.031	0.20	0.65	26.9	0.052	0.115	0.139	0.190
24	30.063093°	31.078205°	0.73	0.10	0.021	0.20	0.51	9.8	0.074	0.098	0.123	0.184
25	30.062194°	31.078056°	0.66	0.21	0.033	0.22	0.55	9.2	0.046	0.092	0.119	0.182
26	30.062228°	31.078938°	1.23	0.26	0.028	0.30	0.27	17.5	0.083	0.156	0.207	0.342
27	30.061712°	31.078510°	0.54	0.30	0.022	0.30	0.35	7.7	0.044	0.088	0.121	0.251
28	30.062824°	31.075927°	0.78	0.29	0.018	0.40	0.41	20.9	0.067	0.094	0.124	0.229
29	30.064998°	31.073955°	0.79	0.22	0.024	0.30	0.28	22.9	0.091	0.123	0.157	0.213
30	30.063908°	31.074979°	4.92	0.39	0.025	0.50	0.43	17.3	0.078	0.102	0.158	0.226
Egyptian limit [53]			290	5.2	5.6	17.4	14	No Egyptian limit and the limit in OEHHA (60) [54]	-	3	3	10

*OEHHA: The Office of Environmental Health Hazard Assessment

Table 4 shows a comparison of air pollutants concentration levels in the current study with those recorded in wastewater treatment plants in other countries. This table indicates that CO and particulate matter (PM_1, $PM_{2.5}$, PM_{10}, and TSP) in the current study are higher than the results in the previous studies [16, 55]; while NH_3, H_2S and VOC are lower than the results in most other studies.

Table 4
Comparing the results of Air Pollutants concentration in Abu-Rawash WWTP with those found around the world

Country	City	Mean concentration levels (mg/m^3)									
		CO	SO_2	NO_2	NH_3	H_2S	VOC	PM_1	$PM_{2.5}$	PM_{10}	TSP
Egypt *	Abu-Rawash	1.82	0.40	0.034	0.35	0.37	14.4	0.099	0.140	0.191	0.290
Taiwan [16]	Taipei	0.733	-	-	ND	ND	225	0.00137	0.00320	0.0135	0.0169
	North	0.859	-	-	1.07	10.35	92	0.00123	0.00857	0.03442	0.04521
	Subtropical	-	-	-	3.48	0.279	-	-	-	0.14	0.34
USA [15, 56-58]	Iowa	-	-	-	-	2.38	-	-	-	-	-
		-	-	-	-	0.204	-	-	-	-	1.91
Portugal [59]	Porto	-	-	-	1.39	135.7	-	-	-	-	-
Brazil [60]	Curitiba	-	-	-		0.032	-	-	-	-	-
USA [55, 61]	Arizona	-	-	-	0.072	-	-	-	0.005	0.023	-
	California	-	-	-	0.369	1.115	-	-	-	-	-
Austria [6]	Vienna	-	-	-	-	-	35.7	-	-	-	-
Australia [62]		-	-	-	0.524	0.307	107	-	-	-	-
Italy [63]	Ancon	-	-	-	0.0037	0.0074	-	-	-	-	-
Spain [1]	Cantabria	-	-	-	-	-	430	-	-	-	-

ND: not detected
* The current study

3.2. Distribution of Data (contour maps)

Figures 2 show the contour maps (concentration distributions) of gaseous air pollutants (CO, SO_2, NO_2, NH_3, H_2S and VOC) at Abu-Rawash WWTP that were plotted using Software Surfer 13 applied to the collected data. The figures showed the presence of two hotspots in Abu-Rawash WWTP; in Sludge building area and coarse strainer area. This means that sludge and strainer processes are responsible for the emission of most gaseous air pollutants, in addition to the combustion activities detected around the WWTP due to burning of agricultural waste. A car park was also found nearest these areas while the measurements were taken.

The contour maps of particulate matter of different fraction sizes (PM_1, $PM_{2.5}$, PM_{10}, and TSP) in Abu-Rawash WWTP are shown in Figures 3. It can be seen that highest concentrations of particulate matter were distributed over two sampling areas; at Sludge building area and near tanks of sludge area. This means that sludge precipitation process contribute to the particulates emission. Figures 3 also clearly showed that the location of the potential source of particulate matter was identified at the northwest of the plant. This location is surrounded by combustion activities due to burning of agricultural residues and is affected by vehicle emissions coming from the main roads in the northwest direction.

The potential source of air pollutants at northwest (NW) direction is confirmed by the results of meteorological parameters (temperature, humidity, wind speed and wind directions) which recorded during the sampling period (Figure 4). Figure 4 shows the Wind-Rose plot of the meteorological data for Abu-Rawash WWTP, whereas the concentration levels of particulate matter varied depending on meteorological parameters and different unit operations. The temperature was ranged from 10 ℃ to 36 ℃, the precipitation was ranged from 0 mm to 16 mm, wind speed was ranged from 2.18 m/s to 6.8 m/s, and wind direction varied between (north (N), west (W), north west (NW), north east (NE), south west (SW)) while the most predominant wind direction was north west (NW).

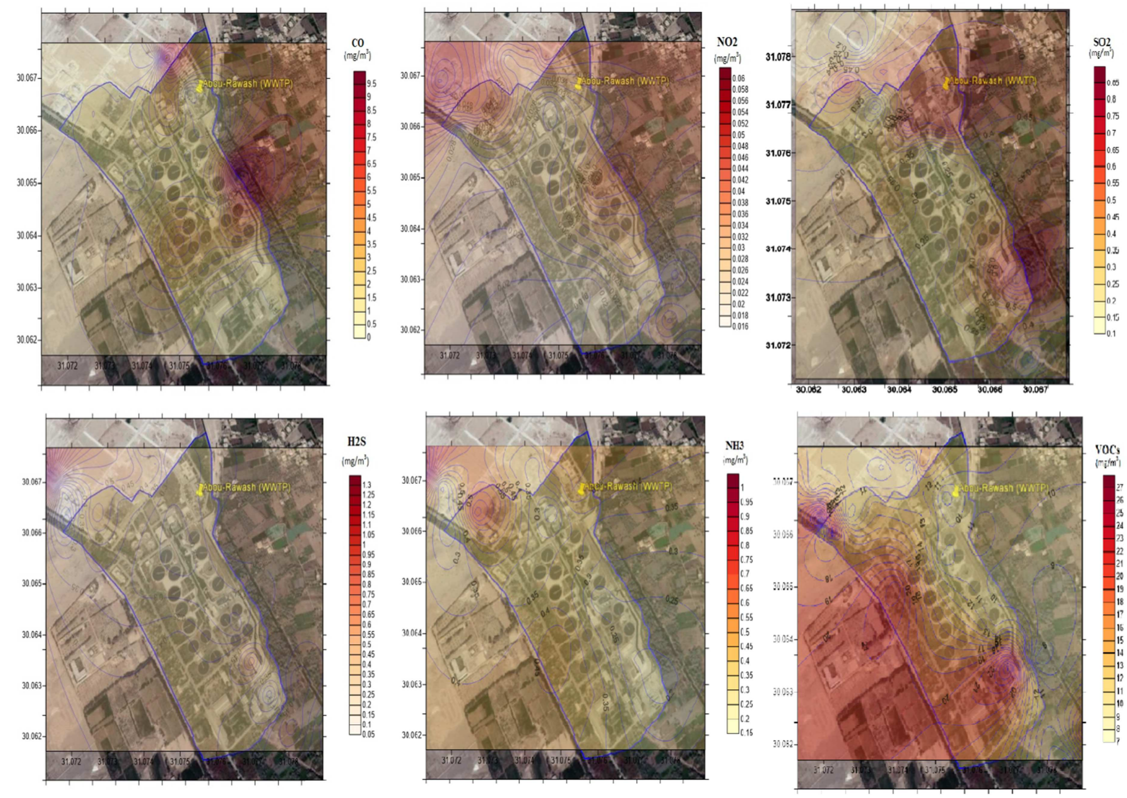

Figure 2: Contour maps of gaseous air pollutants (CO, SO_2, NO_2, NH_3, H_2S, and VOC) concentration levels in Abu-Rawash WWTP

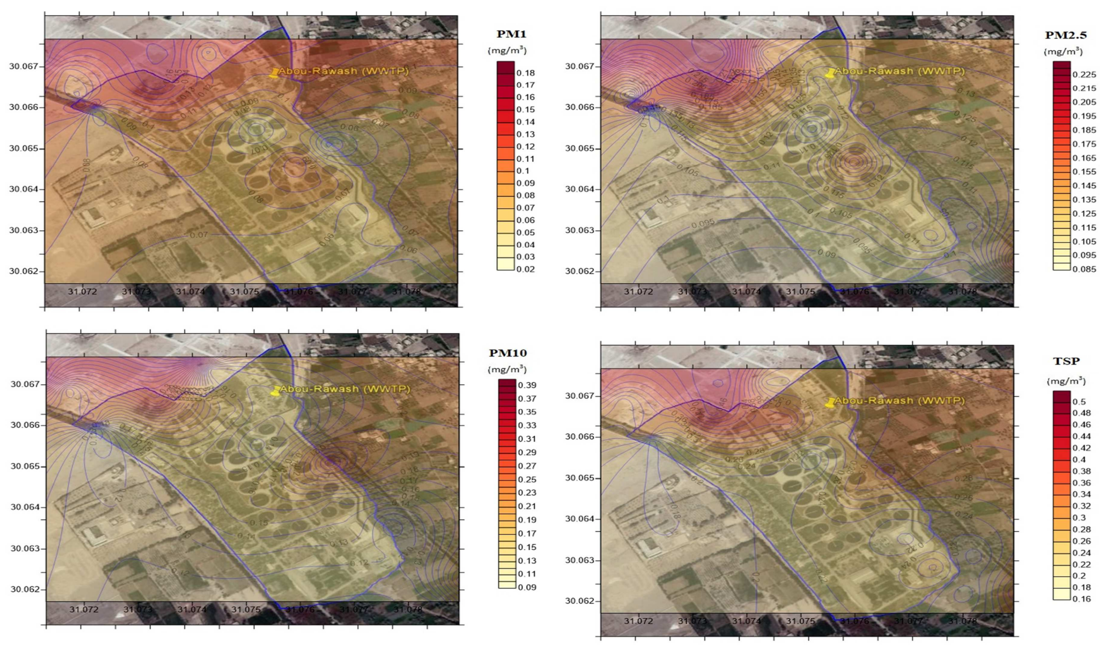

Figure 3: Contour maps of Particulate matter (PM_1, $PM_{2.5}$, PM_{10}, and TSP) concentration levels in Abu-Rawash WWTP

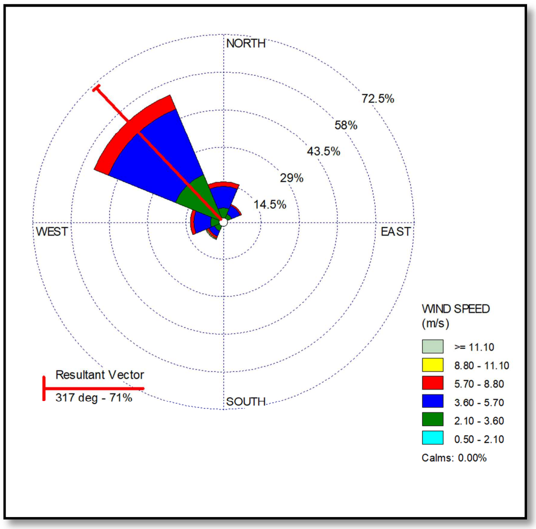

Figure 4: Wind-Rose plot of meteorological data for Abu-Rawash WWTP

3.3. Health Risk Assessment

In the present study, non-carcinogenic risk was evaluated as a hazard quotient (HQ, dimensionless). Results in Figure 5 show the HQ of air pollutants detected in Abu-Rawash WWTP. This figure shows that the highest risk for non-carcinogenic originated from VOC compounds. Figure 5 also shows that HQ < 1 for all air pollutants, except for H_2S, and VOC, which indicates that there are chronic adverse health effects caused by exposure to H_2S, and VOC according to US EPA (2017) [35]. Hazard index (HI, dimensionless) is calculated as sum of hazard quotient of air pollutants in Abu-Rawash WWTP. Results show that HI equal 57.3, which is greater than 1; these indicate that there is adverse chronic health effects occur due to exposure to pollutant in Abu-Rawash WWTP according to US EPA (2017) [35].

Cancer risk of VOCs was estimated according to the inhalation unit risk and reference dose values for carcinogenic effects. Lifetime cancer risk (LCR, dimensionless) was evaluated for volatile organic compounds emitted in Abu-Rawash WWTP. The calculated LCR for VOCs was 0.0513, which is greater than ($0.0001 = 10^{-4}$); indicating that there is a high potential for cancer risk according to the US Environmental Protection Agency (2017) [35].

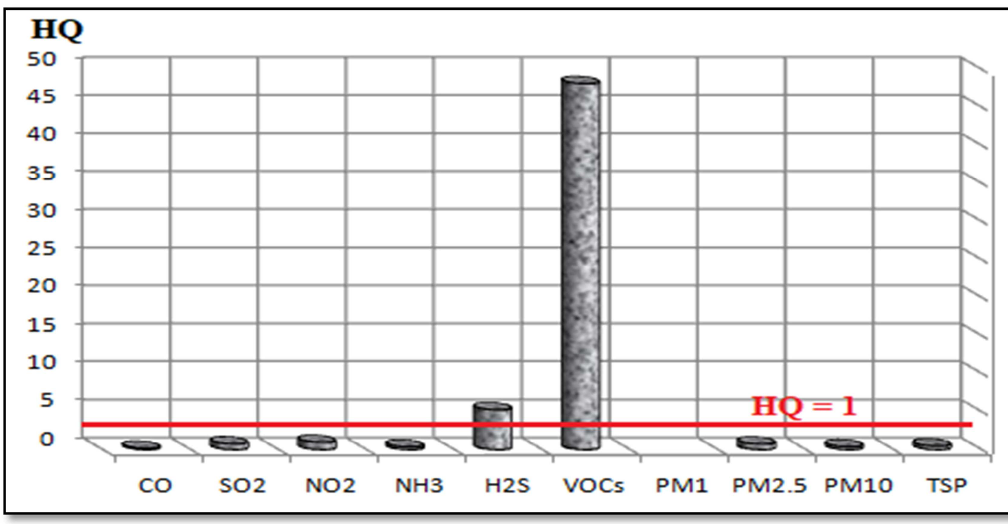

Figure 5: HQ of air pollutants detected in Abu-Rawash WWTP

4. Conclusions

Prominent air pollutants (CO, SO_2, NO_2, NH_3, H_2S, TVOC, PM_1, $PM_{2.5}$, PM_{10}, and TSP) were monitored at 30 sites in Abu-Rawash wastewater treatment plant to evaluate profile of air pollution. The results indicated that all concentration levels of pollutants were below the permissible thresholds in Labour Law No. 12 of 2003 and Environmental Protection Law No. 4 of 1994 and its executive regulations amended by Cabinet Resolution 1095 of 2011 in the Arab Republic of Egypt.

Software Surfer 13 was applied on data collected to plot contour maps of air pollutants. The contour maps of gaseous pollutants indicated the presence of two hotspots at Sludge building area and coarse strainer area which means that, sludge and strainer processes are responsible for the emission of most gaseous air pollutants, in addition to the combustion activities detected around the WWTP due to burning of agricultural waste. In addition, a car park was also found near these areas.

The contour maps of particulate matter (PM_1, $PM_{2.5}$, PM_{10}, and TSP) indicated that the highest concentrations of particulate matter were distributed at Sludge building area and near tanks of sludge area, meaning that sludge precipitation process contribute to the particulates emission. The location of the potential source of particulate matter was identified at the northwest of the plant that may be due to such location is also surrounded by combustion activities due to burning of agricultural residues and is affected by vehicle emissions coming from the main roads in the northwest direction. The potential source of air pollutants at northwest direction is confirmed by the Wind-Rose plot of the meteorological data. The identification of the air pollutant sources is the initial step in order to select the technology of air pollution control.

Non-carcinogenic risk is evaluated as hazard quotient (HQ). The highest risk for non-carcinogenic originated from VOC compounds. HQ were less than 1 for all air pollutants, except H_2S, and VOC, which indicate that there is adverse chronic health effects caused by exposure to H_2S, and VOC. In addition, Hazard index (HI) is equal 57.3, which is greater than 1; indicating that there is adverse chronic health effects occur due to exposure to air pollutants in Abu-Rawash WWTP. The lifetime cancer risk of volatile organic compounds was (0.0513) greater than 10^{-4} which categorized as high cancer risk according to US EPA (2017). Finally, our findings provide a basis for improving the air quality in Abu-Rawash WWTP in order to control the health risk of workers and the residents nearest the plant.

5. Conflicts of interest

There are no conflicts to declare.

6. Formatting of funding sources

There are no funding received to assist with the preparation of this manuscript.

7. Ethical Approval

All Data in the current study was collected accordance with the ethical standards. For this type of study formal consent is not required.

8. Availability of data and materials

Some or all data, models, or code that support the findings of this study are available from the corresponding author upon reasonable request.

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