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Emission rates of pollutants from Ready Mix Concrete plants in Cairo, Egypt

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Abstract

Ready Mixed Concrete (RMC) plants mix cement, sand, aggregates and water to produce a ready-to-use material. In the present study, pollutants emitted from RMC plants as particulate matter (TSP, PM_{10} and $PM_{2.5}$), and gaseous pollutants (CO, NO_2, SO_2, H_2S and VOC) were monitored at working areas from five RMC Plants in Cairo, Egypt, during 2019. The mean concentrations of TSP, PM_{10} and $PM_{2.5}$ during different processes in RMC plants were 0.28-3.23 mg/m^3, 0.11-1.45 mg/m^3 and 0.07-0.64 mg/m^3, respectively. The total emissions rate of TSP, PM_{10} and $PM_{2.5}$ from RMC plants were 0.78-1.42 g/s, 0.24-0.43 g/s and 0.03-0.06 g/s, respectively. Higher emission rates of gases were recorded at plants with higher working hours, higher generator consumption of diesel and higher equipment consumption of diesel. Finally, result shows that the main sources of PM and gaseous pollutants in RMC plants are mixer process, truck movement on unpaved roads and using generators. Recommendation for RMC plant are: it should be cover storage areas; use water sprayer system for loading sand and aggregates; use control system at mixer area; and roads inside RMC plant should be paved and washed every day.

Keywords: Ready Mix Concrete (RMC); Particulate matter; PM_{10}; $PM_{2.5}$; Gaseous pollutants; Emissions rate.

1. Introduction

Ready Mixed Concrete (RMC) is an old technology, as old as 1903, when it was first patented in Germany. This industry in Europe & USA witnessed remarkable growth in the latter half of the 20th century; and spread its wings in smaller countries of Europe & East Asian countries [1]. RMC is defined as a concrete type that is mixed by batch plants using different processes such as handling raw materials, batching and mixing concrete, loading the admixtures, and then delivering to construction sites [2, 3]. RMC is a ready-to-use material, with a predetermined mixture of cement, sand, aggregates and water. It is a type of concrete manufactured in a factory according to a set recipe or as per specifications of the customer at a centrally located batching plant. Ready Mixed Concrete is usually ordered in units of cubic yards or meters [4]. Figure (1S) shows the materials used in ready mixed concrete manufacture [5]. All the materials required for RMC should be stored in such a way as to prevent the risk of air contamination and the different materials should be stored separately by taking due precautions and care, to avoid intermixing [1].

In the manufacture processes of RMC, sand, aggregate, cement, and water are all gravity fed from a weigh hopper into the mixer trucks. The cement is transferred to elevated storage silos. The sand and coarse aggregate are transferred to elevated bins. From these elevated bins, the constituents are fed by gravity or screw conveyor to weigh hoppers, which combine the proper amounts of each material [6-8]. The admixtures or RMC must remain in motion until it is ready to be poured, otherwise the cement may begin to solidify [4].

In RMC plants, pollution emissions occur at discrete and definable locations during various activities such as sand and aggregate transfer to the conveyor; sand and aggregate transfer to the weigh hopper; loading of cement and cement supplement silos; RMC load-out into trucks; and from electricity generators fuelled by oil (Fig. 2S) [1, 9-12]. Dust emissions are the potential impacts associated with concrete batching plants [10]. RMC plants generate

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and disperse varying amounts of dust during routine operations. Particulate matters ($PM_{2.5}$ and PM_{10}) were emitted into atmosphere from a number of locations within the concrete plant and the plant property [13]: loading/unloading of raw materials in trucks, trailers and tankers; delivery of cement and fly ash during silo loading; delivery and stockpiling of aggregates; handling aggregate processing (crushing, screening); loading and drawing down aggregate bins; aggregate and cement weighing; truck mixer loading and charging; vehicle traffic and wind erosion from sand and aggregate storage piles (Fig. 3S) [14, 15]. In addition, a major source of potential PM emission is the movement of heavy trucks over unpaved or dusty surfaces in and around the plant [5, 13]. The amount of fugitive emissions generated during the transfer of sand and aggregate depends primarily on the surface moisture content of these materials [5, 16]. PM problems can be alsoarisen by sitting the concrete batching plant in prevailing high winds. The prevailing wind direction should be considered during the planning proposal, to ensure that bunkers and conveyors are sited out of the leeward direction [10].

Sensitive land uses include residential areas and zones, hospitals, schools, caravan parks or other similar uses (Fig. 4S). To protect the sensitive land uses, buffer distances are designed to minimize any potential impacts due to fugitive air emissions. A minimum buffer distance of 100 meters between RMC plants and sensitive land uses is included in recommended buffer distances for industrial residual air emissions [10]. Controlling PM emissions from RMC plants may include water sprays, enclosures, hoods, curtains, central duct collection systems, and the like.

In Delhi, India, about 25-30 million m^3 of ready-mixed concrete were produced from around 400-500 RMC facilities [1]. USEPA [14] stated that, in California, USA, in addition to PM, pollutants emitted from RMC were carbon monoxide (CO), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), and volatile organic compounds (VOC).Local air quality in RMC plants can also be impacted by PM emissions containing $PM_{2.5}$ and PM_{10}. These much smaller particles pose an occupational health and safety risk for workers who inhale these particles for prolonged periods of time without proper respiratory protection equipment [13]. Fine PM can also enter neighboring premises in the area and adversely affect amenity [10].

The processes at RMC plants, such as sand and aggregate processing, include main conveyor loading and unloading, sand sieving, sized aggregate and the load-out into trucks. These processes lead to emissions of different size of particulates (TSP, PM_{10} and $PM_{2.5}$). In addition, using diesel generators inside RMC plants to supply electricity lead to emissions of gaseous pollutants such as: NO_2, SO_2, VOCs, H_2S and CO resulting from using diesel fuels [14].

The current study was aimed to: i) Monitoring concentrations of the fugitive dust emitted from the different processes in Ready Mixed Concrete (RMC) plants in Cairo, Egypt; ii) Evaluate emissions rate of particulate matter (TSP, PM_{10} and $PM_{2.5}$); iii) Monitoring concentrations of gases pollutants emitted from generators that use for electricity generation in Ready Mixed Concrete (RMC) plants; iv) Evaluate emissions rate of gases pollutants.

2. Experimental Work

2.1. Concrete composition

Concrete composition (% of volume) at most of RMC plants were coarse aggregate (33%), Fine aggregate (26%), Cement (15%), water (20%), and Entrained Air Content (6%) [13, 17-20]. The concrete is mixed on the way to the site where the concrete is to be poured. At some of these plants, the concrete may also be manufactured in a central mix drum and transferred to a transport truck [11].

2.2. Sites description

Air pollutants which emitted from five Ready Mixed Concrete Plants (RMC) were measured during 2019. The RMC plants were selected on the basis of different sites east and west Cairo (Fig. 1). Plant A is located in The 6th October City and Plant B located in El- Sheikh Zayed City (west of Cairo) while plants C and D located on the other side of Cairo (Gesr El-swess area) and plant E located in El-Obour City. Table-1S describes specifications of each RMC plant. The maximum production rate of the RMC plants were 300, 900, 600, 600 and 1000 (m^3/day) for A, B, C, D and E, respectively.

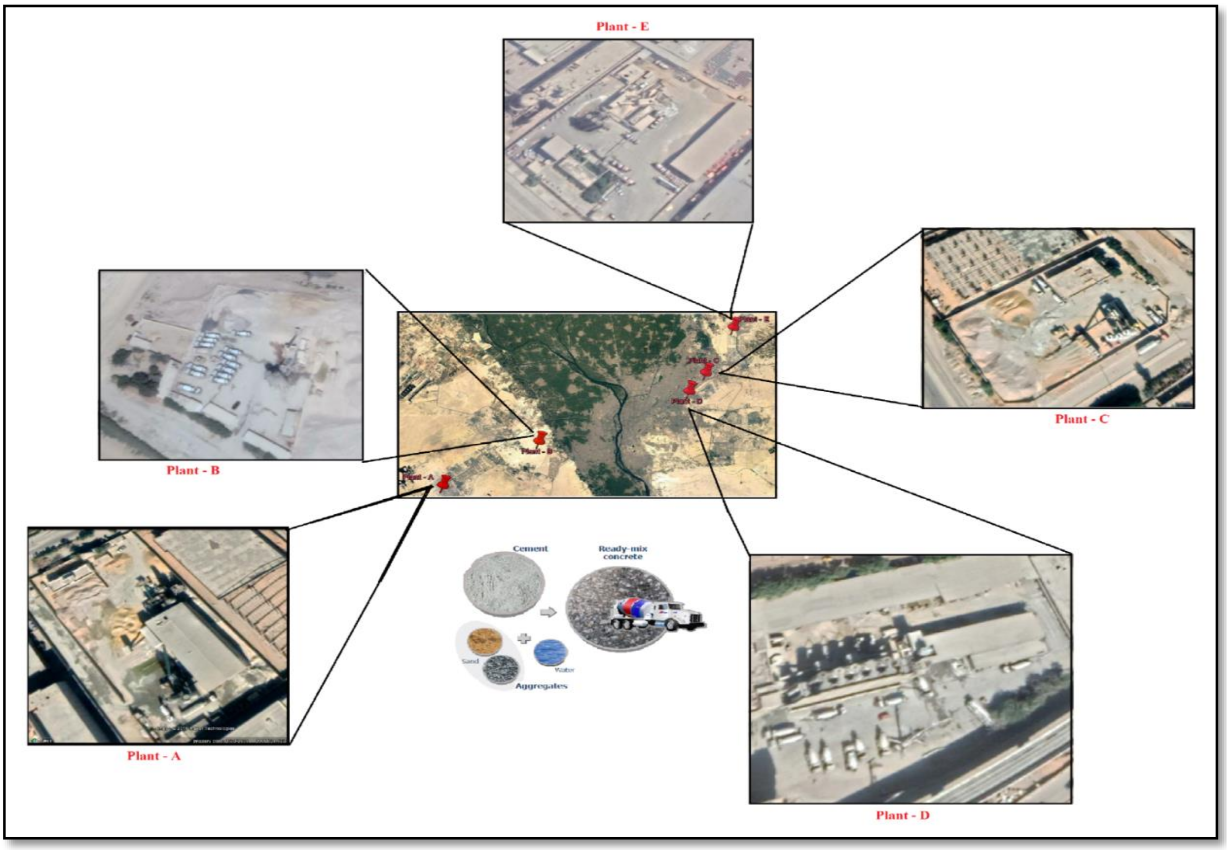

Figure (1): Map showing Ready Mixed Concrete Plants (RMC) in Cairo

2.3. Monitoring the concentration of Air pollutants at working areas

Monitoring of Particulate matters, with different fraction sizes (TSP, PM_{10} and $PM_{2.5}$), occurred during 2019 using CEL-712 Casella Micro-Dust Pro Particulate Monitor. Gaseous pollutants (SO_2, NO_2, CO, H_2S and VOCs) were monitored by using Air Quality Sensor: Aeroqual's Series 500, portable air quality monitors.

2.4. Evaluation of Emissions from Ready Mixed Concrete Plants

Particulates emissions were calculated for the operation of RMC plants by using emission factors from AP42 Chapter 11.2 (Table 1) and Eq. (1).The total emissions from RMC were calculated by Eq. (2) [7, 11, 12, 21-26].

$$\mathbf{E = EF \times Max.\ Loaded\ material \times 1000 \times 1 / 3600} \qquad \mathbf{(1)}$$

Where:

E: particulates emissions from loaded material (g/s)

EF: Emission factor of Loaded Materials (kg/ton)

Max. Loaded material: Maximum throughput, loaded materials [cement, sand and aggregates, (ton/hour)]

1000: conversion factor (g/kg)

1 /3600: conversion factor (1 hour/3600 seconds)

$$\mathbf{E_{RMC} = E_{Cement\ uploading} + E_{Sand\ transfer} + E_{Aggregate\ transfer} + E_{Mixer\ Loading}} \qquad \mathbf{(2)}$$

Where:

E_{RMC}: Total particulates emissions from RMC (g/s)

$E_{Cement\ uploading}$: Particulates emissions from Cement uploading (g/s)

$E_{Sand\ transfer}$: Particulates emissions from Sand transfer (g/s)

$E_{Aggregate\ transfer}$: Particulates emissions from Aggregate transfer (g/s)

$E_{Mixer\ loading}$: Particulates emissions from mixer (g/s)

Table 1:Emission Factor of particulates from Loaded Materials

Loaded Materials	Emission Factor (kg/ton)		
	TSP	PM_{10}	$PM_{2.5}$
Cement - Uploading	0.00099	0.00034	4.42E-05
Sand Transfer	0.0021	0.00099	0.000129
Aggregate Transfer	0.0069	0.0033	0.000429
Mixer Loading	0.0184	0.0055	0.000715

Emissions from gases were calculated by Eq. (3) [6, 27].

$$E_{gas} = Q \times 3600 \times OP_{Hrs} \times C \times m \times M) / 10^6 \quad (3)$$

Where:
E_{gas}: Emissions of gas, kg/yr
Q: Flow rate through exhaust ventilation system, m^3/s
3600: Conversion factor, s/hr
OP_{Hrs}: Exhaust system operating hours, hr/yr
C: Concentration of gas, ppmv
m: Molar volume of gas at 20 °C, mole/m^3
M: Molecular weight of gas, kg/mole
10^6: Conversion factor

3. Results and Discussion

3.1. Air pollutants in working areas

Table 2 and 2S show the mean concentrations (mg/m^3) of particulate matters (TSP, PM_{10} and $PM_{2.5}$) and statistical analysis during different processes in RMC plants at the sampling sites. The mean concentrations of TSP, PM_{10} and $PM_{2.5}$ during different processes in RMC plants were 0.28-3.23 mg/m^3, 0.11-1.45 mg/m^3 and 0.07-0.64 mg/m^3, respectively. Maximum mean concentration of TSP (3.23 mg/m^3) was detected at the storage area of materials of plant B; and maximum concentration of PM_{10} (1.45 mg/m^3) was detected at vibrator area of plant E where the sand were sieved and aggregates were sized. While, maximum concentration of $PM_{2.5}$ (0.64 mg/m^3) was detected at the generators Area of plant D. Generally, high mean concentrations of particulates matter for all fractions (TSP, PM_{10} and $PM_{2.5}$) were detected at the entrance of the plants as a result of vicinity to the main roads where traffics add another load of particulates beside the emission from the plant, and at generators area as a result of using fuel oil. All the detected levels of TSP, PM_{10} and $PM_{2.5}$ were less than the Egyptian Permissible limit in Law No. 4/1994 for dust emitted from industrial activities [28]. Maximum mean concentrations of particulates matter, for all fraction sizes (TSP, PM_{10} and $PM_{2.5}$) are detected in the order: Generators Area > the entrance to the plants > storage area > vibrator area > central mixer (drum) > plants workshops area > control room.

Table 2: The mean concentrations (mg/m^3) of particulates matter (TSP, PM_{10} and $PM_{2.5}$) during different processes in RMC plants at sampling sites.

Site	A			B			C			D			E		
	TSP	**PM_{10}**	**$PM_{2.5}$**	**TSP**	**PM_{10}**	**$PM_{2.5}$**	**TSP**	**PM_{10}**	**$PM_{2.5}$**	**TSP**	**PM_{10}**	**$PM_{2.5}$**	**TSP**	**PM_{10}**	**$PM_{2.5}$**
The entrance to the plants	0.64	0.36	0.22	1.9	0.85	0.57	1.05	0.7	0.32	1.21	0.74	0.4	2.49	0.7	0.41
Central Mixer (drum)	0.66	0.18	0.12	1.79	0.72	0.46	0.6	0.31	0.16	0.7	0.42	0.18	1.85	0.85	0.44
Control Room	0.31	0.12	0.08	0.37	0.18	0.12	0.28	0.12	0.09	0.35	0.11	0.07	0.64	0.26	0.12
Vibrator area	0.43	0.25	0.12	1.7	0.47	0.34	0.75	0.4	0.3	0.72	0.38	0.29	2.25	1.45	0.46
Storage area	0.54	0.26	0.18	3.23	0.71	0.5	0.51	0.3	0.17	0.45	0.26	0.17	2.2	0.58	0.43
Generators Area	-	-	-	2.02	0.71	0.33	1.64	1.01	0.58	1.73	0.99	0.64	2.55	0.73	0.45
Plants workshops area	0.41	0.2	0.19	0.84	0.42	0.31	0.33	0.14	0.1	0.34	0.16	0.09	0.78	0.34	0.2
Statistical analysis: Minimum	0.31	0.12	0.08	0.37	0.18	0.12	0.28	0.12	0.09	0.34	0.11	0.07	0.64	0.26	0.12
Statistical analysis: Mean	0.50	0.23	0.15	1.69	0.58	0.38	0.74	0.43	0.25	0.79	0.44	0.26	1.82	0.70	0.36
Statistical analysis: Maximum	0.66	0.36	0.22	3.23	0.85	0.57	1.64	1.01	0.58	1.73	0.99	0.64	2.55	1.45	0.46
Statistical analysis: Standard deviation	0.14	0.08	0.05	0.91	0.23	0.15	0.48	0.32	0.17	0.51	0.32	0.20	0.79	0.39	0.14
Egyptian limit*	**10**	**3**	**3**	**10**	**3**	**3**	**10**	**3**	**3**	**10**	**3**	**3**	**10**	**3**	**3**

*Egyptian limit in working areas, source: (EEAA, 1994 [28])

Figure 2 shows the mean concentrations (mg/m^3) of particulates matter (TSP, PM_{10} and $PM_{2.5}$) emitted from all the processes of RMC plants. TSP levels in all investigated plants were 0.43 – 1.82 mg/m^3 with mean value 1.09 mg/m^3, while PM_{10} were 0.20 – 0.70 mg/m^3 with mean value 0.47 mg/m^3, and $PM_{2.5}$ were 0.13 – 0.38 mg/m^3 with mean value 0.27 mg/m^3. Maximum mean concentrations of (TSP, PM_{10} and $PM_{2.5}$) emitted from the investigated plants were detected in plants E and B due to the higher daily production rate compared with other plants.

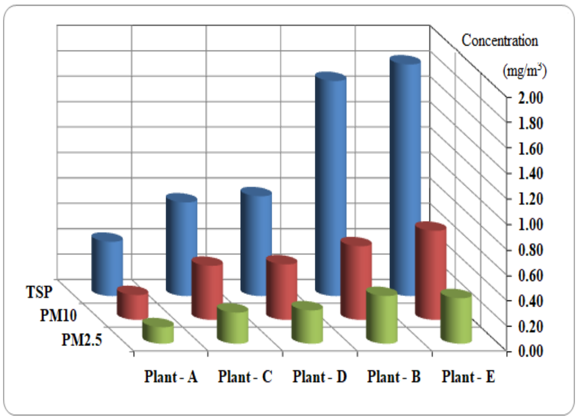

Fig. 2: The mean concentrations of particulates matter (TSP, PM_{10} and $PM_{2.5}$) emitted from all the processes of RMC plants during 2019.

Table 3 shows the mean levels of gaseous pollutants (NO_2, SO_2, VOCs, H_2S and CO) resulted from RMC plants containing generators for electricity. All the detected levels of gaseous pollutants were also less than the Egyptian Permissible limits in Law No. 4/1994 for industrial activities (working areas) [28].

Table 3: Mean levels of gaseous pollutants (NO_2, SO_2, VOCs, H_2S and CO) resulted from RMC plants containing generator.

Site	A	B	C	D	E	Egyptian limit*
NO_2	0.06	0.04	0.06	0.25	0.05	5.6 mg/m^3
SO_2	0.12	0.04	0.21	0.24	0.25	5.2 mg/m^3
VOCs**	1.36	1.58	9.50	9.77	12.63	25 mg/m^3
H_2S	0.10	0.14	0.11	0.16	0.22	14 mg/m^3
CO	0.62	3.68	1.25	1.10	0.93	29 mg/m^3

*Source: (EEAA, 1994 [28]) ** Source: (NEQ, 2015 [29])

In addition, Table 3 shows also that the highest gaseous emissions were recorded at plant E which was attributed to the higher daily consumption rate of diesel fuel for equipment (such as trucks) and generators for electricity in such plant compared with others.

Table 3S showed the comparison between levels of pollutants from RMC plants in the current study and other plants at USA. The results show that TSP, PM_{10}, $PM_{2.5}$, SO_2 and CO levels in the current study are higher than the levels recorded by TPH (2015) [20] in Toronto, USA, while, NO_2 levels are lower. While, PM_{10} levels in the current study are lower than the levels recorded by Richards and Brozell (2005) [18] at North Carolina, USA, and $PM_{2.5}$ levels are higher.

3.2. Particulate Emission rate from RMC plants

Table 4 shows the total emission rates (g/s) of TSP, PM_{10} and $PM_{2.5}$ from each process in RMC plants during 2019. It shows that highest emission rates of particulate matter (TSP, PM_{10} and $PM_{2.5}$) were recorded at mixer process. It can be concluded that the emission rate from the processes are in the order: mixer > aggregate transfer > sand transfer > cement uploading. The total emission rates of TSP, PM_{10} and $PM_{2.5}$ from RMC plants were 0.78-1.42 g/s, 0.24-0.43 g/s and 0.03-0.06 g/s, respectively.

Fig. 5a shows the emissions percentage (%) of each process in each RMC plants. The percentages of TSP emissions were 96.5 - 98.6 %, 2.45 –0.92 %, 0.77 – 0.29 % and 0.28 – 0.19 %; while emission percentage of PM_{10} and $PM_{2.5}$ were 94. 7 - 97.8 %, 3.8 –1.5 %, 1.18 – 0.48 % and 0.32 – 0.22 % at mixer, aggregate transfer, sand transfer and cement uploading, respectively. Fig. 5b shows the emissions percentage (%) of each process in all RMC plants. The percentage of TSP were 0.2 %, 0.4 %, 1.4 %, 98 %; PM_{10} and $PM_{2.5}$ were 0.2 %, 0.7 %, 2.1 %, 97 % from cement uploading, sand transfer, aggregate transfer and mixer, respectively. It shows emission percentage of TSP, PM_{10} and $PM_{2.5}$ in all plants were in order: mixer > aggregate transfer > sand transfer > cement uploading.

Table 4: The emission rates (g/s) of TSP, PM_{10} and $PM_{2.5}$ from each process in RMC plants during 2019.

PM	Emission rate (g/s)	A	B	C	D	E	Mean Emission rate (g/s)
TSP	Cement uploading	0.0028	0.0028	0.0022	0.0022	0.0028	0.0025
	Sand transfer	0.004	0.004	0.006	0.006	0.004	0.0048
	Aggregate transfer	0.013	0.013	0.019	0.019	0.013	0.0157
	Mixer	1.40	1.40	0.76	0.76	1.40	1.1398
	Total from plant	1.42	1.42	0.78	0.78	1.42	1.1628
PM_{10}	Cement uploading	0.0009	0.0009	0.0008	0.0008	0.0009	0.0009
	Sand transfer	0.0019	0.0019	0.0028	0.0028	0.0019	0.0023
	Aggregate transfer	0.0064	0.0064	0.0092	0.0092	0.0064	0.0075
	Mixer	0.42	0.42	0.23	0.23	0.42	0.3407
	Total from plant	0.43	0.43	0.24	0.24	0.43	0.3513
$PM_{2.5}$	Cement uploading	0.00012	0.00012	0.00010	0.00010	0.00012	0.00012
	Sand transfer	0.00025	0.00025	0.00036	0.00036	0.00025	0.00025
	Aggregate transfer	0.0008	0.0008	0.0012	0.0012	0.0008	0.0008
	Mixer	0.054	0.054	0.029	0.029	0.054	0.054
	Total from plant	0.06	0.06	0.03	0.03	0.06	0.06

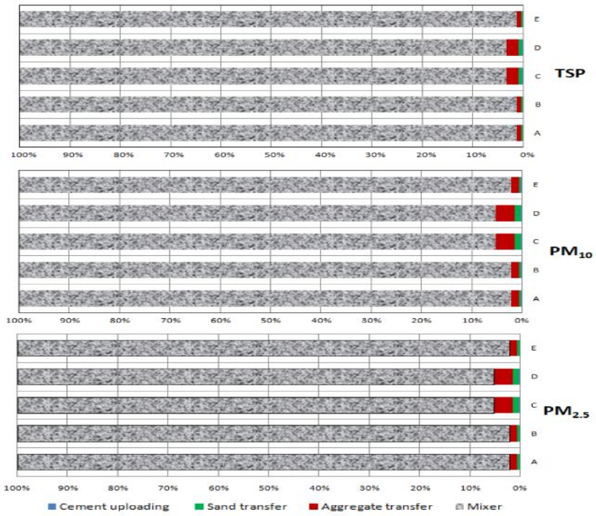

Fig. 5a: Emission (%) of each process in each RMC plants

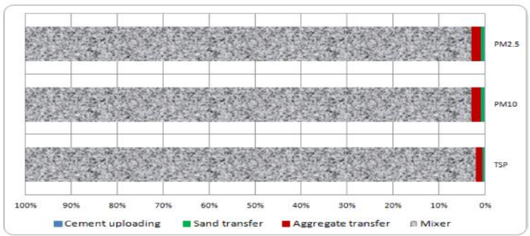

Fig. 5b : Emission (%) of each process in all RMC plants

Fig. 5: Emissions of particulate matters (TSP, PM_{10} and $PM_{2.5}$) from RMC plants

3.3. Gaseous Emissions rate from RMC plants

RMC plants are containing generators for electricity, and diesel exhaust emissions from the concrete trucks. Fig. 6 shows the mean emission rates (g/s) of gaseous pollutants (NO_2, SO_2, VOCs, H_2S and CO) emitted from generators and concrete trucks in RMC plants during 2019. The emission rates of gases ranged between 0.13-7.56 (g/s) for NO_2; 0.103-24.21 (g/s) for SO_2; 6.0E-07 – 7.3E-05 (g/s) for VOCs; 0.025-3.08 (g/s) for H_2S and 0.145- 25.3 (g/s) for CO. Higher emission rates of gases were recorded at plant E and plant B due to higher working hours, higher generator consumption of diesel and higher equipment consumption of diesel.

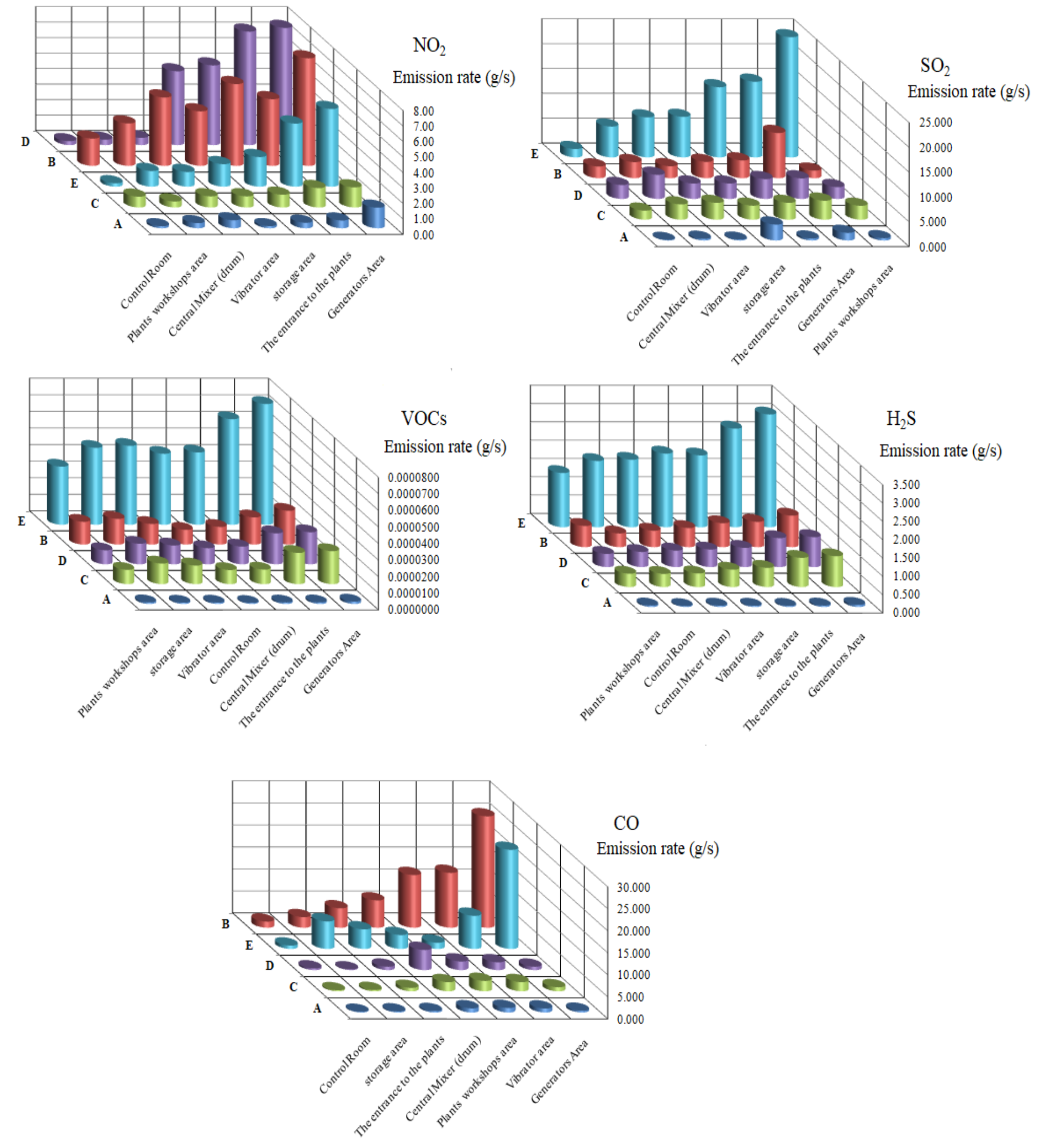

Fig. 6: Mean emissions rate of gaseous pollutants (NO_2, SO_2, VOCs, H_2S and CO) from processes at RMC plants (g/s).

Results in Table 5 shows mean emission rates (g/s) of gaseous pollutants (NO_2, SO_2, VOCs, H_2S and CO) from processes in RMC plants. The highest emission rates of NO_2 were detected at generators Area, while the highest emission rates of SO_2, VOCs, H_2S and CO were detected at the entrance to the plants. These results are attributed to the consumption of diesel for generator and trucks beside the vicinity to the main roads where traffics add another load of gases. The Figure shows that CO and SO_2 were the higher emission rates than all other investigated gases in all plants. It shows that emission of gases were in the order of: CO $\approx SO_2 > NO_2 > H_2S >$ VOCs. In addition, Table 5 shows emissions percentages of gaseous pollutants (NO_2, SO_2, VOCs, H_2S and CO) from processes at RMC plants. The figure shows that highest percentages of gaseous emissions were found at generators area and the entrance to the plants, which may be attributed to consumption of diesel fuels used for generator and trucks. The percentages of gases that contribute from the processes were in the order: generators area > the entrance to the plants > storage area > vibrator area > central mixer (drum) > plants workshops area > control room.

Table 5: Mean emission rates (g/s) and percentages (%) of gaseous pollutants (NO_2, SO_2, VOCs, H_2S and CO) from processes in RMC plants.

Site	NO_2	SO_2	VOCs	H_2S	CO
Mean emission rates (g/s)					
Generators Area	4.428	6.272	0.000027	1.132	9.977
The entrance to the plants	3.489	6.764	0.000024	1.002	4.944
storage area	2.702	5.097	0.000015	0.739	3.742
Vibrator area	2.117	4.112	0.000014	0.704	3.386
Central Mixer (drum)	1.411	3.421	0.000017	0.630	2.140
Plants workshops area	0.962	3.542	0.000017	0.596	1.869
Control Room	0.611	1.749	0.000013	0.565	0.582
Total emissions from RMC plant	15.719	30.958	0.000127	5.368	26.642
Percentages (%)					
Generators Area	28.2	20.3	21.1	21.1	37.4
The entrance to the plants	22.2	21.8	18.7	18.7	18.6
storage area	17.2	16.5	11.7	13.8	14.0
Vibrator area	13.5	13.3	11.1	13.1	12.7
Central Mixer (drum)	9.0	11.1	13.1	11.7	8.0
Plants workshops area	6.1	11.4	13.8	11.1	7.0
Control Room	3.9	5.6	10.5	10.5	2.2

Table 4S shows the comparison between emissions rate (g/s) of particulate matter and gases from RMC plants in the current study and others at USA and Serbia. The results show that the emission rates of TSP in the current study are (0.78-1.42 g/s) higher than that recorded by Richards and Brozell (2004) [17], MDEQ (2011) [23], Woodson (2012) [30] and Marinković (2013) [31] at Virginia (7.21 g/s), California (1.4E-07 - 29E-07 g/s), Portland (0.272-0.544 g/s) in USA and Belgrade (0.711-0.628 g/s) in Serbia. The emission rates of PM_{10} are (0.24-0.43 g/s) also higher than that recorded by MDEQ (2011) [23], AQR (2017) [5], Woodson (2012) [30] and Marinković (2013) [31] at California (0.0279-0.00001 g/s), North Carolina (1.4 E-08 - 73E-08 g/s), Portland (0.067-0.134 g/s) in USA and Belgrade (0.193-0.199 g/s) in Serbia. While, they are lower than that recorded by Richards and Brozell (2004) [17] and USEPA (2003) [14] at Virginia (2.19 g/s) and Nevada (2.73 g/s) in USA. The emission rates of $PM_{2.5}$ are (0.031-0.055 g/s) higher than that recorded by MDEQ (2011) [23], AQR (2017) [5] and Marinković (2013) [31] at California (0.0067-0.000002 g/s), North Carolina (28E-08 - 1.7E-08 g/s) in USA and Belgrade (0.0015- 0.045 g/s) in Serbia, while they are lower than that recorded by Richards and Brozell (2004) [17] and USEPA (2003) [14] at Virginia (0.07 g/s) and Nevada (1.04 g/s)in USA.

In addition, the mean emission rates of H_2S (0.04-2.12 g/s) and VOC (9.04E-07 – 5.2E-07 g/s) in the current study are lower than that recorded by Richards and Brozell (2004) [17], USEPA (2003) [14] and Marinković (2013) [31] at Virginia (0.07 g/s) and Nevada (0.39 g/s) in USA and Belgrade (0.076-0.737 g/s) in Serbia. Mean emission rates of NO_2 are (0.47-4.14 g/s) higher than that recorded by Richards and Brozell (2004) [17], USEPA (2003) [14], MDEQ (2011) [23] and Marinković (2013) [31] at Virginia (1.01 g/s), Nevada (1.24 g/s), California (0.038 g/s) in USA and Belgrade (0.016-0.486 g/s) in Serbia. Mean SO_2 emission rates are (0.89-11.09 g/s) higher than that recorded by Richards and Brozell (2004) [17], USEPA (2003) [14], MDEQ (2011) [23] and Marinković (2013) [31] at Virginia (0.45 g/s), Nevada (0.61 g/s), California (0.0001 g/s) in USA and Belgrade (0.005-0.17 g/s) in Serbia. Mean CO emission rates are (0.57-9.16 g/s) also higher than that recorded by Richards and Brozell (2004) [17], USEPA (2003) [14], MDEQ (2011) [23] and Marinković (2013) [31] at Virginia (0.24 g/s), Nevada (2.09 g/s), California (0.142 g/s) in USA and Belgrade (0.004-0.723 g/s) in Serbia.

4. Conclusion

In the current study, results shows that the mean concentrations of TSP, PM_{10} and $PM_{2.5}$ monitored during different processes in RMC plants were less than the Egyptian Permissible limit in Law No. 4/1994 for dust emitted from industrial activities (working areas). Generally, high levels of particulates matter (TSP, PM_{10} and $PM_{2.5}$) were detected at the entrance of the plants as a result of vicinity to the main roads where traffics add another load of particulates beside the emission from the plant, and at generators area as a result of using fuel oil. Maximum mean concentrations of particulates matter, for all fraction sizes (TSP, PM_{10} and $PM_{2.5}$) are detected in the order: Generators Area > the entrance to the plants > storage area > vibrator area > central mixer (drum) > plants workshops area > control room.

All the detected levels of gaseous pollutants were less than the Egyptian Permissible limits in Law No. 4/1994 for industrial activities (working areas). Highest gaseous emissions were recorded at plant E which was attributed to the higher daily consumption rate of diesel fuel for equipment (such as trucks) and generators for electricity in such plant compared with others. Also, VOCs levels show the highest concentration of emitted gases followed by CO levels.

Highest emission rates of particulate matter (TSP, PM_{10} and $PM_{2.5}$) were recorded at mixer process. It can be concluded that the emission rate of particulate matter from the processes are in the order: mixer > aggregate transfer > sand transfer > cement uploading. Higher emission rates of gases were recorded at plant E and plant B due to higher working hours, higher generator consumption of diesel and higher equipment consumption of diesel. CO and SO_2 were the highest emission rates of all other investigated gases in all plants. The highest percentages of gaseous emissions were found at generators area and the entrance to the plants, which may be attributed to consumption of diesel fuels used for generator and trucks. The percentages of gases that contribute from the processes were in the order: generators area > the entrance to the plants > storage area > vibrator area > central mixer (drum) > plants workshops area > control room.

Finally, result shows that the main sources of PM and gaseous pollutants in RMC plants are mixer process, truck movement on unpaved roads and using generators. So authors recommended that RMC plant should be cover storage areas; use water sprayer system for loading sand and aggregates; use control system at mixer area; and roads inside RMC plant should be paved and washed every day.

5. References

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