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Original Research Article

Assessment of air quality in bus terminal stations in Eastern Province, Kingdom of Saudi Arabia

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ABSTRACT

Background: Bus terminal represent a significant air pollution problem. The use of diesel engines by public transport vehicles results in several air pollutants inside the bus termini. The major source of poor air quality includes industrial activities and traffic pollution that might have great deterioration impact upon the public health and surrounding environment. The main pollutant resulting from bus exhaust emissions are, by mass, carbon dioxide (CO_2), Sulfur dioxide (SO_2), nitrogen oxides (NOx), carbon monoxide (CO), particulate matter (PM), hydrocarbons (HC), volatile organic compounds (VOC) and BETEX (benzene, toluene, ethyl benzene and the three isomers of xylene). Bus fleets represent a significant part of inner city traffic. The present study aimed to assess air quality of bus terminal stations in Eastern Province of Saudi Arabia.
Methods: This study was conducted at different bus terminal stations in Eastern Province. The location was chosen randomly. Air quality monitors were used for analyzing VOCs, CO, CO_2, NO_2, SO_2 and O_3 concentrations. BETEX and PM fractions were measured by applying infrared spectroscopy techniques and dust collection calibrated devices respectively.
Results: Data of indoor and outdoor air pollution revealed that levels of NO_2, SO_2, CO, VOCs, PM10, PM4, PM2.5 and PM1.0 are higher than the permissible exposure limits and Saudi air quality guidelines in bus stations terminal in Dammam, Alhassa and Hafr Albatin bus stations garage, parking and waiting area in morning and noon time respectively.
Conclusions: Ambient concentrations of gaseous and particulate air pollutants are above international guidelines at the different bus terminal sites in eastern provinces and these represent environmental and health risk for public and surrounding environment.

Keywords: Air pollution, Bus terminal stations, Kingdom of Saudi Arabia

INTRODUCTION

Eastern Province has the largest and the most important governorates in the Kingdom of Saudi Arabia (KSA) from both the number of population and the developed economy points of view. It considered as industrial zone as many industrial cities were established as in Dammam, Al Hasa and Al Jubial respectively.[1]

The major sources of poor air quality include industrial activities and traffic pollution that might have great deterioration impact upon the public health and surrounding environment. Moreover, Air quality might be

affected due to presence of large industries areas as well as traffic pollution impact.

The air quality of covered bus termini has always been overseen. However, the air quality inside covered bus termini is as important as the indoor air quality (IAQ) in offices or other public premises. This is because the passengers will queue up and wait for the buses along the bus lanes and they are waiting just beside the vehicle exhaust and the cover of the bus termini does not allow a fast dispersion or dilution of the pollutants.

Poor air quality affects the health (acute health effect and chronic health effect) and comfort of people.[2] The vehicle exhaust in bus termini will damage passenger's lungs such as causing irritation and inflammation in lungs, and even increase the probability of lung cancer.[3] Diesel engines are usually used in buses.

Recent studies have found that diesel transit buses in particular have been singled out as substantial mobile PM sources in urban environments. Those persons waiting at bus stops and who routinely use public transit will have acute and chronic exposure to diesel emissions in high concentrations that can cause acute and chronic illness.

Particulate matter is generally classified into four categories based on the particles size. PM10 (coarse particles), PM2.5 (fine particles), and PM1.0 (very fine particles) that represent high risk of particulate related diseases.[4]

The main pollutant resulting from bus exhaust emissions are, by mass, carbon dioxide (CO_2), Sulfur dioxide (SO_2), nitrogen oxides (NOx), carbon monoxide (CO), particulate matter (PM), hydrocarbons (HC), volatile organic compounds (VOC) and BETEX (benzene, toluene, ethyl benzene and the three isomers of xylene). Bus fleets represent a significant part of inner city traffic. This may cause increased pollutant exposures due to exhaust emissions. The present study was aimed to assess air quality of bus terminal stations in Eastern Province of Saudi Arabia.

METHODS

Site description

The Saudi public transport company (SAPTCO) company provides a wide and regular network of inter-city lines city connecting more than (385) cities, villages and small villages all over the Kingdom. The local services of the company (inter-city) covers five main cities in the Kingdom namely (Riyadh, Mecca, Medina, Jeddah and Dammam).

The bus station is used as a parking, exchange, and maintenance facility. Activities at the bus terminal include mechanical inspection, fuel supply, and maintenance operations.

Study location

This study was conducted at SAPTCO. This cross - sectional study was carried out in selected bus terminal stations in the Eastern Province, KSA in the period from February to June 2014. The location was chosen randomly. Five sampling locations were selected for the purpose of air quality parameters sampling (Figure 1-4).

Station I: Dammam bus station terminal.
Station II: Dammam bus garage station.
Station III: Al-Hasa bus station.
Station IV: Al-Hasa garage bus station.
Station V: Hafar Al-Batin bus station.

Figure 1: Dammam bus terminal station garage sampling area location.

Figure 2: Dammam bus terminal station parking and waiting areas location.

Figure 3: Al-Hassa bus terminal station parking, garage and waiting areas location.

Figure 4: Hafer Albaten bus terminal station parking and waiting area locations.

Instrument suite

Air quality monitors (IAQRAE systems) for VOCs, CO and CO_2 concentrations measurements. However, for NO_2, SO_2 and O_3 Gray wolf gas monitor instrument was used.

BETEX (benzene, toluene, ethyl benzene and the three isomers of xylene) were measured by applying infrared spectroscopy techniques using thermo scientific Miran sapphire XL calibrated instrument.

PM fractions were measured using calibrated dust monitoring device. However, meteorological factors as temperature (c), relative humidity (%) and wind speed (km/hour) were measured using calibrated equipment (kestrel)

Statistical analysis

The data were entered and analyzed by using Statistical Package for the Social Sciences (SPSS) software, version 16 (SPSS Inc., Chicago, IL). Descriptive statistics, independent t-test and ANOVA techniques were used for measuring statistical significance of the studied parameters.

RESULTS

Table 1-3, shows mean levels of gaseous air quality in Dammam, Al-Hasa and in Hafer-Al-Batin bus stations garage, parking and waiting area in morning and noon time respectively. Data of indoor and outdoor air pollution revealed that levels of NO_2, SO_2, CO, VOCs are higher than the permissible exposure limits and Saudi air quality guidelines. However, levels of CO_2 and O_3 are below the Saudi air quality guidelines and these reflect the impact of bus emissions to the outdoor and indoor environment.

Table 1: ANOVA comparison between mean levels of air pollutants in Dammam bus terminal station.

Parameters	Morning				Noon			
	Parking	Waiting	Garage	P-Value	Parking	Waiting	Garage	P-Value
CO ppm	9.71±0.89	1.38±0.02	10.51±0.05	<0.05	6.77±0.74	0.64±0.07	9.64±1.5	<0.05
CO_2 ppm	985±29.8	860±23.45	958±27.63	>0.05	891±16.07	732±23.6	986±22.8	>0.05
NO_2 ppm	0.64±0.11	0.22±0.09	0.75±0.15	<0.05	0.47±0.21	0.14±0.01	0.50±0.01	<0.05
SO_2 ppm	0.73±0.17	0.33±0.04	0.90±0.35	<0.05	0.81±0.22	0.69±0.02	1.44±0.01	<0.05
VOCs ppm	0.44±0.03	0.24±0.09	0.26±0.10	<0.05	0.41±0.12	0.27±0.03	0.58±0.01	<0.05
O3 ppm	0.07±0.02	0.04±0.01	0.14±0.03	>0.05	0.08±0.03	0.05±0.01	0.15±0.05	>0.05

Table 2: ANOVA comparison between mean levels of air pollutants in Dammam bus terminal station Al-Hasa bus terminal station.

Parameters	Morning				Noon			
	Parking	Waiting	Garage	P-Value	Parking	Waiting	Garage	P-Value
CO ppm	9.3±3.4	1.6±0.03	9.31±3.1	<0.05	6.5±1.4	1.8±0.5	9.4±2.5	<0.05
CO_2 ppm	664.3±30.1	712.6±42.02	661±28.8	>0.05	683±33.4	663.66±20.3	791±28	>0.05
NO_2 ppm	0.33±0.52	0.12±0.01	0.9±0.1	<0.05	0.74±0.5	0.13±0.01	1.1±0.91	<0.05
SO_2 ppm	0.66±0.08	0.31±0.01	0.81±0.5	<0.05	0.68±0.17	0.43±0.09	0.96±0.17	<0.05
VOCs ppm	0.45±0.12	0.17±0.06	0.25±0.02	<0.05	0.39±0.02	0.3±0.04	0.44±0.11	<0.05
O_3 ppm	0.03±0.05	0.05±0.05	0.12±0.05	<0.05	0.07±0.05	0.05±0.05	0.14±0.05	<0.05

In Table 4-6, data shows that mean levels of BETEX compounds in Dammam, Al-Hasa and in Hafer-Al-Batin bus stations garage, parking and waiting area in morning and noon time respectively are below the Saudi air quality guidelines although some parameters showed significant association in parking, garage and waiting areas and these might due to modifying factors as temperature, humidity and wind speed (meteorological factors) in Dammam, Al-Hasa and in Hafer-Albaten respectively.

Concerning particulate emissions, Table 7-9 shows that the higher levels of different particulate sizes (PM10, PM4, PM2.5 and PM1 in Dammam, Al-Hasa and in

Hafer-Al-Batin bus stations garage, parking and waiting area in morning and noon time respectively and these might be due to the nature of diesel fuel emissions in parking and garage areas especially in the morning time in comparison with the similar levels in noon time in Dammam, Al-Hasa and in Hafer-Albaten respectively.

Table 3: ANOVA comparison between mean levels of air pollutants in Dammam bus terminal station Hafar Al-Batin bus terminal station.

Parameters	Morning			Noon		
	Parking	Waiting	p -Value	Parking	Waiting	p -Value
CO ppm	9.8±1.5	2.7±0.5	<0.05	9.2±2.3	0.8±0.05	<0.05
CO_2 ppm	528±15.2	487±29.1	>0.05	829±22.5	934±34.1	>0.05
NO_2 ppm	0.54±0.16	0.14±0.05	<0.05	0.44±0.01	0.12±0.01	<0.05
SO_2 ppm	0.94±0.18	0.30±0.11	<0.05	0.69±0.20	0.33±0.09	<0.05
VOCs ppm	0.42±0.20	0.21±0.05	<0.05	0.38±0.18	0.18±0.05	<0.05
O_3 ppm	0.07±0.01	0.42±0.01	>0.05	0.08±0.02	0.02±0.01	>0.05

Table 4: ANOVA comparison between mean levels of BETEX air pollutants in Dammam bus terminal station.

	Morning				Noon			
	Parking	Waiting	Garage	p-Value	Parking	Waiting	Garage	p-Value
Benzene ppm	0.96±0.11	0.33±0.05	0.14±0.05	<0.05	0.6±0.1	0.33±0.05	0.42±0.01	<0.05
Toluene ppm	0.43±0.05	0.3±0.1	0.12±0.05	>0.05	0.26±0.05	0.16±0.05	0.45±0.05	>0.05
Xylene ppm	1.133±0.15	0.3±0.1	0.34±0.01	>0.05	1.23±0.15	0.53±0.11	1.37±0.01	>0.05
Ethyl benzene ppm	2.56±0.05	0.13±0.05	1.44±0.01	<0.05	1.66±0.15	0.13±0.05	1.65±0.05	<0.05

Table 5: ANOVA comparison between mean levels of BETEX air pollutants in Al-Hasa bus terminal station.

Parameter	Morning				Noon			
	Parking	Waiting	Garage	P-value	Parking	Waiting	Garage	P-value
Benzene ppm	0.76±0.04	0.26±0.04	0.13±0.01	<0.05	0.30±0.10	0.26±0.01	0.25±0.05	>0.05
Toluene ppm	0.26±0.01	0.16±0.06	0.11±0.01	>0.05	0.36±0.05	0.13±0.04	0.32±0.02	>0.05
Xylene ppm	0.53±0.03	0.13±0.05	0.23±0.02	<0.05	0.60±0.10	0.23±0.05	0.72±0.01	<0.05
Ethyl benzene ppm	1.30±0.10	0.10±0.02	1.25±0.03	<0.05	1.30±0.10	0.13±0.07	1.34±0.01	<0.05

Table 6: Comparison of mean levels of BETEX air pollutants in Hafar Al-Batin bus terminal station.

Parameters	Morning			Noon		
	Parking	Waiting	p-Value	Parking	Waiting	p-Value
Benzene ppm	2.2±0.1	0.16±0.11	<0.05	0.34±0.01	0.21±0.02	<0.05
Toluene ppm	0.23±0.02	0.13±0.01	>0.05	0.12±0.05	0.11±0.01	>0.05
Xylene ppm	0.41±0.01	0.11±0.05	>0.05	0.32±0.03	0.19±0.04	>0.05
Ethyl benzene ppm	0.51±0.04	0.47±0.07	>0.05	0.31±0.05	0.21±0.07	>0.05

Table 7: ANOVA comparison between mean levels of particulate (PM) air pollutants in Dammam bus terminal station.

	Morning				Noon			
	Parking	Waiting	Garage	p -Value	Parking	Waiting	Garage	p -Value
PM 1 µg/m³	40.33±56	17±43	97.63±22	<0.05	67.66±35	56±25	112±44	<0.05
PM 2.5 µg/m³	132.66±28	24±11	91.77±59	<0.05	154.66±25	45±28	109±27	<0.05
PM 4 µg/m³	182±28	133.33±12	163.93±22	<0.05	166±47	123.33±12	210±32	<0.05
PM 10 µg/m³	485.33±55	142.33±35	365.9±38	<0.05	411.33±15	125±13	282.7±39	<0.05

Figure 5, represents data of meteorological factors revealed that to a great extent these factors modify the levels of gaseous and particulate air pollutants in form of dispersion or dilution in Dammam, Al-Hasa and in Hafer-Al-Batin bus stations garage, parking and waiting area in morning and noon time respectively.

Table 8: ANOVA comparison between mean levels of particulate (PM) air pollutants in Al-Hasa bus terminal station.

Parameters	Morning				Noon			
	Parking	Waiting	Garage	p-Value	Parking	Waiting	Garage	p-Value
PM 1 µg/m³	144.3±19.8	80.2±11.8	131.7±25.9	<0.05	159.3±33.7	96.3±14.1	151.7 ±16.9	<0.05
PM 2.5 µg/m³	190.5±12.5	188.6±18.9	149.35±19.3	<0.05	156±21.5	86.6±15.5	159.2±16.2	<0.05
PM 4 µg/m³	124.6±11.2	121.3±14.9	152.1±19.2	<0.05	128.6±12.4	90.6±10.2	162.86±34.2	<0.05
PM 10 µg/m³	418.3±25.8	211.33±15.2	455.9±33.2	<0.05	332.6±22.8	204±31.2	464.09±45.1	<0.05

Table 9: Comparison between mean levels of particulate (PM) air pollutants in Hafar Al-Batin bus terminal station.

Parameters	Morning			Noon		
	Parking	Waiting	p-Value	Parking	Waiting	p-Value
PM 1 µg/m³	118.3±17.7	85.5±9.9	<0.05	119.8±22.2	99±24.3	<0.05
PM 2.5 µg/m³	222.9±24.5	112.8±13.3	<0.05	120.8±15.3	93.8±10.23	<0.05
PM 4 µg/m³	128.8±11.2	118.8±18.4	<0.05	244.1±21.3	137.8±18.2	<0.05
PM 10 µg/m³	822.3±88.1	182.1±21.5	<0.05	682.8±66.6	172.3±4.8	<0.05

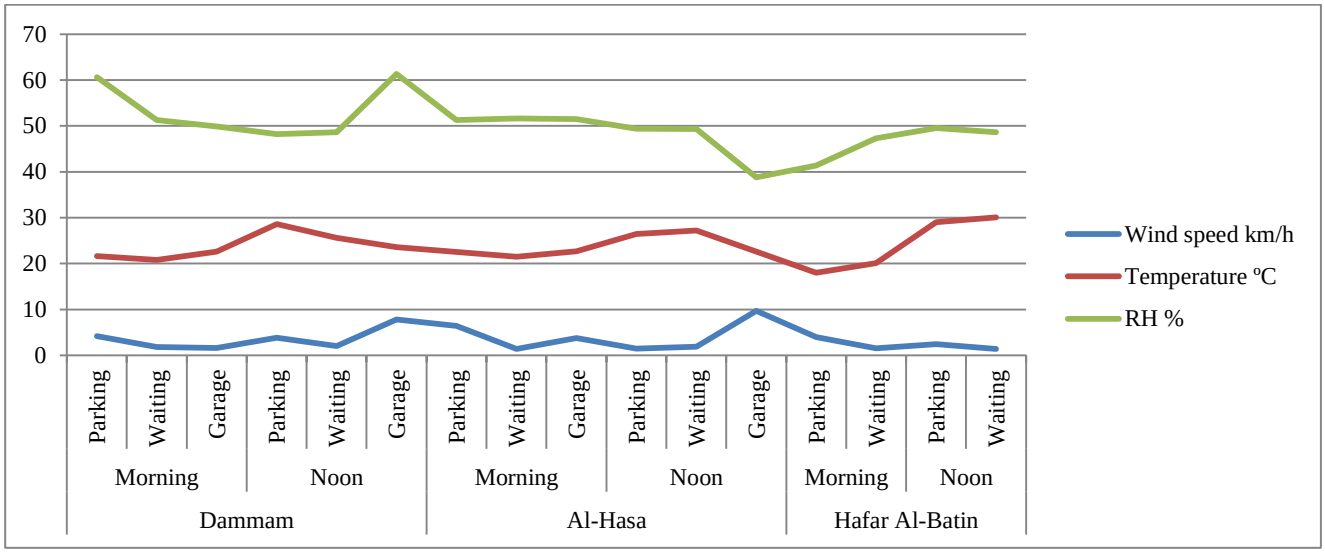

Figure 5: Variations of meteorological factors in different studied locations.

DISCUSSION

Increasing demand on transportation service are main problems in urban cities of developing countries. The majority of cities with high level of ambient air pollution are found in developing countries.[5,7]

The main cause of diesel emissions in buses is the engines which continue running while refueling process resulting in exhaust fumes as well as vapors are present in the station leading to high levels of gaseous and particulate air pollutants. However, close to the refueling station is a large enclosed workshop for buses maintenance and repairs take place. These bad environmental conditions as might increase the levels of gaseous and particulate air emissions.

The average BETEX ambient concentration results in the studied areas in Dammam, Al-Hasa and Hafar Al-Batin at morning and noon period, parking, Garage and weighting areas respectively shows insignificant association when compared with air quality guidelines and this might be due to all studied area are opened and are mainly affected by meteorological factors as wind speed, temperature and humidity. However, that data of the present study are in accordance with similar study that revealed that, there is a statistically insignificant difference between concentrations of BETEX found in individual offices, bus station area and workshop.[8,9] Moreover the elevated levels of BETEX in waiting area might be due to its location close to bus stations area where, buses are refueled, diesel exhaust emissions from the idling buses considered the main cause of elevation of BETEX concentrations.

In bus station terminal in all studied location measured levels of PM10 and PM4, PM2.5 and PM1.0 are significantly higher than air quality guidelines. This finding is in accordance to the results of another study, which was previously conducted in the same two cities.[1]

In the present study the data of gaseous air pollutants shows higher significant for the mean levels of CO, VOCs, SO_2 and NO_2 in the studied areas in Dammam, Al-Hasa and Hafar Al-Batin at morning and noon period, parking, Garage and weighting areas respectively. However, mean levels of CO_2 and O_3 did not showed any significant association in the studied areas in Dammam, Al-Hasa and Hafar Al-Batin at morning and noon period, parking, garage and weighting areas respectively. The higher levels of some of gas air pollutants are might be due to fuel type combustion, buses idling, believed to be an important factor and diesel emissions.

Bus terminal stations and traffic pollution is significantly contributes in the urban air quality problems and have great and serious deterioration impact on the public and surrounding environment.[10]

CONCLUSION

From the present study we can conclude that ambient concentrations of gaseous and particulate air pollutants are generally above international and national air quality guidelines at the different bus terminal sites in eastern provinces and these represent environmental and health risk for public and surrounding environment especially in parking and garage area site, and are a matter of concern.

Recommendations

From the results of the present study we urgently recommend to relocation all bus terminals in eastern province to outside residential and commercial zone aiming to protect the deterioration impact of air pollutants emissions from bus terminal stations

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