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Fuel Stations Impact on Occupational Air Quality in Egypt and Saudi Arabia

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Abstract

During gas station operation, unburned fuel can be released into the environment through distribution, delivery, and storage. In recent years, global gas station leaks have caused persistent groundwater pollution, posing threats to both ecosystems and human health. In this study, legislation governing gas stations in Egypt and Saudi Arabia was compared. Total volatile organic compounds (TVOCs), sulfur dioxide (SO_2), carbon monoxide (CO), nitrogen monoxide (NO), nitrogen dioxide (NO_2), particulate matter less than 10 micrometers (PM_{10}), particulate matter less than 2.5 micrometers ($PM_{2.5}$), and noise were measured at two gas stations in both countries, and a soil sample was taken from Saudi fuel station to analyze benzene, toluene, ethylbenzene, xylene (BTEX), and total petroleum hydrocarbons (TPH). The measurements of air pollutants and noise levels indicate variations between Egypt and Saudi Arabia. Total volatile organic compounds (TVOCs), sulfur dioxide (SO_2), carbon monoxide (CO), nitrogen monoxide (NO), nitrogen dioxide (NO_2), particulate matter less than 10 micrometers (PM_{10}), particulate matter less than 2.5 micrometers ($PM_{2.5}$), and noise levels are generally higher in Saudi Arabia compared to Egypt. Results of benzene, toluene, ethylbenzene, and xylene (BTEX) measurements in soil were less than 0.001 mg/kg, and the results of measuring total petroleum hydrocarbons (TPHs) were lower than 2.30 mg/kg for $C_6 – C_{10}$, $C_{10} – C_{16}$ and $C_{16} – C_{34}$ fractions, while $C_{34} – C_{50}$ fraction was lower than 0.001 mg/kg. All measured parameters were within permissible limits in both Egypt and the Kingdom of Saudi Arabia in accordance with the Egyptian Environmental Law, the Egyptian Labor Law for Egypt and OSHA standards for Saudi Arabia. Effective measures need to be implemented to mitigate air pollution and noise levels, including stricter emission standards, promotion of cleaner energy sources, and urban planning strategies to reduce traffic congestion and noise pollution. Continuous monitoring and assessment of air quality and noise levels are crucial for informing policy decisions and public health interventions aimed at improving environmental conditions and safeguarding human health in both Egypt and Saudi Arabia.

Keywords: PM, BTEX, VOCs, Gas filling station, Air Quality.

Introduction

For decades, air pollution is considered a major problem on a local, national, and international scale. There are air quality limits for pollutants that can be emitted into the atmosphere in many different countries. Numerous epidemiological studies have confirmed that prolonged exposure to air pollution is linked to declines in lung functions as well as a number of other health issues (**Air Quality Guidelines for Europe, 2000; Garzón et al., 2015; Lerner et al., 2012)**. There are several strong pieces of evidence supporting the link between cardiovascular disease and air pollution **(Novikova et al., 2014)**. Particles or heavy metals in the atmosphere that are extremely dangerous to human health and the environment are known as air pollutants. Benzene, a volatile molecule that mixes with other elements to form gasoline, is one of the primary pollutants. It is commonly known that air pollution from moving vehicles has a negative impact on health outcomes like hospital admissions, mortality, and morbidity. Moreover, there may be significant financial consequences **(Kingham et al., 2013)**.

The operations of fuel stations may also contribute to environmental issues in addition to the transmission of illnesses among employees and nearby residents. For example, the possibility of gasoline and oil spilling into the earth and groundwater, as well as the alteration of the surrounding region's aesthetics, particularly when the gas station is situated in a densely populated residential area **(Najar et al., 2023)**.

The primary threat to the environment and human health is air pollution, which is mostly brought on by motor vehicles and the activities that go along with them, including filling up with fuel **(Gupta & Dogra 2002; Archibald et al., 2018)**. Over 2% of the complex mixture of hydrocarbons that makes up gasoline are aromatic compounds, with the remaining 95% being aliphatic and alicyclic molecules. Certain ones could have consequences that are carcinogenic, mutagenic, or genotoxic. There is a significant danger of fume exposure and its consequences for workers at gas stations. Even for brief inhalations, petrol vapor concentrations in the atmosphere are dangerous **(Pranjic et al., 2002; Lewné et al. 2006)**. Employees at fueling stations work eight hours a day and typically don't wear personal protective equipment. Two primary factors make volatile organic compounds (VOCs) a worry for the environment: the creation of secondary organic aerosols and tropospheric ozone, as well as health issues resulting from poisonous, cancer-causing, and mutagenic VOCs **(Williams & Koppmann, 2007)**.

The primary pathways for VOC exposure are skin contact and inhalation. This can lead to symptoms such as headache, dizziness, nausea, vomiting, hand numbness, difficulty concentrating, forgetfulness, and eye problems (swollen eyes, dry eyes, strained vision, tired and irritated eyes, difficulty discriminating colors), skin rashes and itching, gastrointestinal issues, respiratory issues (infections, asthma, lung function abnormalities, inflammation of the nose), fatigue, lethargy, odor complaints, neurobehavioral issues, psychological problems, and various cardiovascular diseases **(Tabinda et al., 2019)**. Therefore, in this research, volatile organic compounds were measured in addition to other pollutants such as NO_2, NO, CO, SO_2, $PM_{2.5}$, and PM_{10} , as well as noise levels.

Setback lengths are a type of legislation designed to protect people from the cancer risk associated with toxic evaporative emissions from gas stations, which is dependent on how far away the station is from the public **(Wu et al., 2006)**. In the United States, several states have varying setback distance regulations, and even within States, individual counties may establish their own regulations. The California Air Resources Board (CARB) advises against placing new sensitive land uses, like daycare centers and schools, within 300 feet (91 meters) of a large gasoline dispensing facility. A large gasoline dispensing facility is defined as having an annual sales volume of at least 3.6 million gallons **(Mohai et al., 2020)**. This recommendation is based on estimates of lifetime cancer risk. However, a zoning amendment requiring gas stations that pump more than 3.6 million gallons of gas annually to be 500 feet away from public and private schools, parks, playgrounds, recreational areas, homes, and environmentally sensitive areas was approved by a county council in the US state of Maryland **(Montgomery County Council, 2015)**. The treatment of sales volume as a categorical number in these cases leads to a loss of accuracy and makes the assumption that the link between cancer risk and exposure is constant across all sales volumes in a specific category. Furthermore, no setback lengths that explain the existence of gas station clusters are known to exist. The impact of sales volume and the number of gas stations in a cluster on the risk of cancer from fuel spills and evaporative fuel losses should be investigated in order to strengthen rules on setback distances for gas stations **(Hsieh et al., 2021)**.

Gasoline station workers are exposed to volatile organic compounds such as benzene, toluene, ethylbenzene, and xylene (BTEX). **Tunsaringkarn et al. (2012)** declared that BTEX concentrations in gasoline station in Bangkok, Thailand, were 0.006, 0.008, 0.007 and 0.002, respectively.

Benzene, toluene, ethylbenzene, and xylene (known collectively as BTEX) are types of volatile organic compounds. Benzene and ethylbenzene are recognized as carcinogens. Benzene can also impact the hematopoietic system, the central nervous system, and the reproductive system. **(National Institute of Environmental Health Sciences, 1993)**. Toluene can also have effects on both the reproductive and central nervous systems **(US Environmental Protection Agency, 2005)**. Ethylbenzene and xylene can cause respiratory and neurological problems in workers at petrol stations **(Tunsaringkarn et al., 2012)**.

Materials and Methods

Air & Soil Pollution Measurements

Study Area

Air and soil pollutants were measured in two gasoline fuel stations in:

- Saudi Arabia, In the Asir region - Rijal Al Maa Governorate - King Abdulaziz Road
    - The fuel station is located on a highway and is surrounded by restaurants, administrative buildings, and car workshops.
    - The station was built on a plot of land of 2,000 square meters.

- The amount of fuel supplied is about 45,000 liters per week, and the filling rates are 14,000 liters per week for gasoline 95
- The amount of fuel supplied is about 45,000 liters per week, and the filling rates are 28,000 liters per week for gasoline 92

- Egypt, Alexandria Government - Smouha
  - The fuel station is located close to residential buildings, schools, and medical clinics.
  - The station was built on a plot of land of 1,200 square meters.
  - The amount of fuel supplied is about 45,000 liters per week, and the filling rates are 28,000 liters per week for gasoline 95
  - The amount of fuel supplied is about 45,000 liters per week, and the filling rates are 28,000 liters per week for gasoline 92

Fig. 1. Fuel station location in Saudi Arabia.

Fig. 2. Fuel station location in Egypt.

Sampling Sites

- Air pollutants were measured in four sites within each gasoline fuel station (fueling area, maintenance area, washing area, and near storage tanks).
- Samples were collected at 15-minute intervals over 4 hours, resulting in a total of 16 samples per site.
- Soil pollutants were measured in a sample collected at depth of 40 – 50 cm.

- Samples were collected in Saudi Arabia on October 4, 2023, and in Egypt on October 15, 2023

Similarities of weather at both countries during sampling

The predominant wind direction is different in both Egypt and Saudi Arabia, as illustrated in Figs. 3 & 4. In Saudi Arabia, the predominant wind direction is north-eastern, while in Egypt, the predominant wind direction is north-western and south- western.

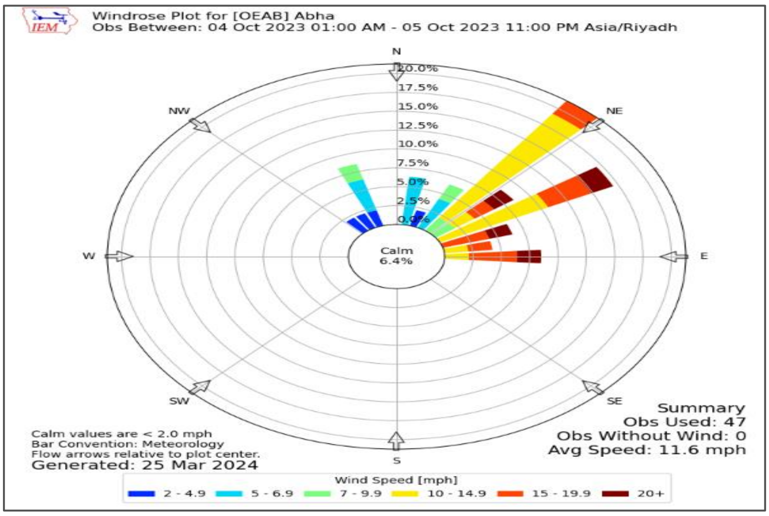

Fig. 3. Shows the wind rose observed at the measuring site throughout the measurement day in Saudi Arabia.

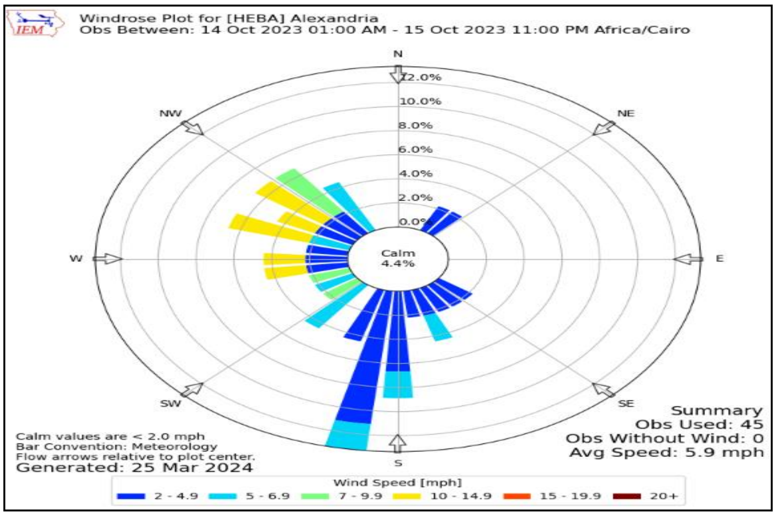

Fig. 4. Shows the wind rose observed at the measuring site throughout the measurement day in Egypt.

- Tables 1 and 2 compare the weather conditions in both Egypt and Saudi Arabia on the measurement day. The tables illustrate similarities in temperature and humidity in both countries, with a slight difference in wind speed.

Table 1. Shows weather history during measuring day in Saudi Arabia.

Time	Temperature	Dew Point	Humidity	Wind	Wind Speed	Wind Gust	Pressure	Precip.	Condition
12:00 AM	20 °C	-7 °C	16 %	ENE	9 km/h	0 km/h	796.36 hPa	0.0 mm	Fair
1:00 AM	19 °C	-6 °C	18 %	NNE	9 km/h	0 km/h	796.36 hPa	0.0 mm	Fair
2:00 AM	18 °C	-6 °C	19 %	NNE	11 km/h	0 km/h	795.59 hPa	0.0 mm	Fair
3:00 AM	18 °C	-5 °C	21 %	NNW	7 km/h	0 km/h	795.59 hPa	0.0 mm	Fair
4:00 AM	18 °C	-6 °C	19 %	NW	7 km/h	0 km/h	796.36 hPa	0.0 mm	Fair
5:00 AM	17 °C	-6 °C	20 %	CALM	0 km/h	0 km/h	796.36 hPa	0.0 mm	Fair
6:00 AM	16 °C	-5 °C	23 %	CALM	0 km/h	0 km/h	796.36 hPa	0.0 mm	Fair
7:00 AM	18 °C	-4 °C	22 %	CALM	0 km/h	0 km/h	797.14 hPa	0.0 mm	Fair
8:00 AM	22 °C	-4 °C	17 %	NNE	7 km/h	0 km/h	797.14 hPa	0.0 mm	Fair
9:00 AM	24 °C	-3 °C	17 %	ENE	26 km/h	0 km/h	797.91 hPa	0.0 mm	Fair
10:00 AM	26 °C	-4 °C	14 %	E	24 km/h	43 km/h	797.91 hPa	0.0 mm	Fair
11:00 AM	28 °C	-6 °C	10 %	E	33 km/h	0 km/h	797.14 hPa	0.0 mm	Fair / Windy
12:00 PM	28 °C	-7 °C	10 %	ENE	35 km/h	0 km/h	796.36 hPa	0.0 mm	Fair / Windy
1:00 PM	30 °C	-7 °C	9 %	ENE	31 km/h	0 km/h	795.59 hPa	0.0 mm	Fair
2:00 PM	29 °C	-9 °C	8 %	NE	22 km/h	41 km/h	794.81 hPa	0.0 mm	Fair
3:00 PM	30 °C	-8 °C	8 %	ENE	39 km/h	0 km/h	794.81 hPa	0.0 mm	Fair / Windy
4:00 PM	29 °C	-9 °C	8 %	NE	26 km/h	50 km/h	794.81 hPa	0.0 mm	Fair
5:00 PM	28 °C	-9 °C	8 %	NE	22 km/h	0 km/h	794.81 hPa	0.0 mm	Fair
6:00 PM	26 °C	-9 °C	9 %	NE	24 km/h	0 km/h	795.59 hPa	0.0 mm	Fair
7:00 PM	25 °C	-7 °C	12 %	NE	22 km/h	0 km/h	795.59 hPa	0.0 mm	Fair
8:00 PM	25 °C	-7 °C	12 %	ENE	19 km/h	0 km/h	796.36 hPa	0.0 mm	Fair
9:00 PM	24 °C	-7 °C	12 %	ENE	26 km/h	0 km/h	797.14 hPa	0.0 mm	Fair
10:00 PM	23 °C	-7 °C	13 %	ENE	17 km/h	0 km/h	797.14 hPa	0.0 mm	Fair
11:00 PM	22 °C	-6 °C	15 %	NE	17 km/h	0 km/h	797.14 hPa	0.0 mm	Fair

Table 2. Shows weather history during measuring day in Egypt.

Time	Temperature	Dew Point	Humidity	Wind	Wind Speed	Wind Gust	Pressure	Precip.	Condition
12:00 AM	17 °C	13 °C	77 %	CALM	0 km/h	0 km/h	795.59 hPa	0.0 mm	Fair
1:00 AM	17 °C	5 °C	45 %	E	7 km/h	0 km/h	795.59 hPa	0.0 mm	Fair
2:00 AM	17 °C	2 °C	37 %	CALM	0 km/h	0 km/h	795.59 hPa	0.0 mm	Fair
3:00 AM	16 °C	3 °C	42 %	CALM	0 km/h	0 km/h	795.59 hPa	0.0 mm	Fair
4:00 AM	15 °C	3 °C	45 %	CALM	0 km/h	0 km/h	794.81 hPa	0.0 mm	Fair
5:00 AM	15 °C	-1 °C	34 %	CALM	0 km/h	0 km/h	794.81 hPa	0.0 mm	Fair
6:00 AM	16 °C	-2 °C	29 %	CALM	0 km/h	0 km/h	795.59 hPa	0.0 mm	Fair
7:00 AM	18 °C	-1 °C	28 %	CALM	0 km/h	0 km/h	795.59 hPa	0.0 mm	Fair
8:00 AM	21 °C	-2 °C	21 %	E	7 km/h	0 km/h	796.36 hPa	0.0 mm	Fair
9:00 AM	23 °C	-4 °C	16 %	ESE	22 km/h	0 km/h	796.36 hPa	0.0 mm	Fair
10:00 AM	24 °C	-4 °C	15 %	ENE	15 km/h	0 km/h	796.36 hPa	0.0 mm	Fair
11:00 AM	25 °C	-4 °C	14 %	ESE	15 km/h	0 km/h	795.59 hPa	0.0 mm	Fair
12:00 PM	27 °C	-6 °C	11 %	E	15 km/h	0 km/h	794.81 hPa	0.0 mm	Fair
1:00 PM	27 °C	-5 °C	12 %	N	26 km/h	0 km/h	794.04 hPa	0.0 mm	Fair
2:00 PM	25 °C	8 °C	34 %	SSW	11 km/h	0 km/h	793.26 hPa	0.0 mm	Partly Cloudy
3:00 PM	25 °C	11 °C	41 %	SSW	33 km/h	0 km/h	793.26 hPa	0.0 mm	Partly Cloudy / Windy
4:00 PM	22 °C	12 °C	53 %	SSW	24 km/h	0 km/h	792.49 hPa	0.0 mm	Partly Cloudy
5:00 PM	21 °C	13 °C	60 %	SSW	13 km/h	0 km/h	793.26 hPa	0.0 mm	Partly Cloudy
6:00 PM	20 °C	15 °C	73 %	SSW	13 km/h	0 km/h	793.26 hPa	0.0 mm	Fair
7:00 PM	19 °C	14 °C	73 %	SSW	17 km/h	0 km/h	794.04 hPa	0.0 mm	Fair
8:00 PM	18 °C	13 °C	73 %	SSW	9 km/h	0 km/h	794.81 hPa	0.0 mm	Fair
9:00 PM	18 °C	13 °C	73 %	WNW	7 km/h	0 km/h	794.81 hPa	0.0 mm	Fair
10:00 PM	18 °C	13 °C	73 %	NNW	7 km/h	0 km/h	794.81 hPa	0.0 mm	Fair
11:00 PM	17 °C	12 °C	72 %	SSE	7 km/h	0 km/h	794.81 hPa	0.0 mm	Fair

Sampling Instruments

The different parameters such as PM_{10}, $PM_{2.5}$, noise, organic (total volatile organic compounds) and inorganic gases (SO_2, CO, NO, NO_2,), soil pollutants (benzene, toluene, xylene, and ethylbenzene), and total petroleum hydrocarbons have been measured in the selected stations using mentioned instruments in Tables 3 and 4.

Table 3. Different equipment that were used for fuel station measurements in Egypt.

	**1. Dust Detective** ■ **Instrument Model:** CEL-712 micro dust Pro ■ **Company:** CASELLA CEL. ■ **Parameters:** - Total Suspended Particulates TSP (mg/m^3) - Particulate matter less than 10-micron PM_{10} (mg/m^3) - Particulate matter less than 2.5-micron $PM_{2.5}$ (mg/m^3) ■ **Range:** 0:100 mg/m^3 ■ **Accuracy:** ± 2% ■ **Division:** 0.001 mg/m^3
	**2. Digital Sound Level Meter** ■ **Instrument Model:** AR834 ■ **Company:** SMART SENSOR ■ **Parameters:** Noise Levels (dB) ■ **Range:** 30:130 dB ■ **Accuracy:** ± 2 dB ■ **Division:** 0.1 dB
	**3. Organic and Inorganic Gases Detector** ■ **Instrument Model:** TIGER handheld VOC detector ■ **Company:** IONSCIENCE ■ **Parameters:** - Volatile Organic Compounds: TVOCs - Inorganic Gases: O_2 - NO_2 - CO - H_2S - SO_2 ■ **Range:** 0.001:20000 mg/m^3 ■ **Accuracy:** ± 0.001% ■ **Division:** 0.001 mg/m^3

Results and Discussion

Comparison of Legislations

Started to collect many references, the laws and legislation of the Kingdom of Saudi Arabia and the Arab Republic of Egypt, and the environmental studies that address a topic establishing gas stations, this is to be an information base from which the researcher can start collecting the additional information he needs and forming the required idea about the research problem (Table 5).

Table 4. Different equipment that were used for fuel station measurements in Saudi Arabia.

	**1. SOUND LEVEL METER** ■ **Instrument Model:** CIRRUS IEC 61672-3 2013 ■ **Parameters:** Noise Levels (dB) ■ **Range:** 30:130 dB ■ **Accuracy:** ± 2 dB ■ **Division:** 0.1 dB
	**2. Gas Chromatography–Mass Spectrometry & Chromatography– Flame Ionization Detector** ■ **Instrument Model:** GC-2030AF SHIMADZU ■ **Parameters:** Petroleum indicators
	**3. GRAY WLOF SENSING SOLUTIONS** ■ **Instrument Model:** Wolf Sense IAQ Direct Sense TG-501 and TG-502 Probe ■ **Parameters:** - Particulate matter: PM_{10}, $PM_{2.5}$ Temperature, percent relative humidity (% RH), Dew point, Carbon Monoxide (CO), Sulfur Dioxide (SO_2), Nitrogen Dioxide (NO_2), Hydrogen Sulfide (H_2S), Ammonia (NH_3), Ozone (O_3) and Total Volatile Hydrocarbon (TVOCs). ■ **Range:** 0.001:15000 mg/m^3 ■ **Accuracy:** ± 0.001% ■ **Division:** 0.001 mg/m^3

When comparing regulations and air quality limits in the work environment, it was noted that there is a difference in air quality limits in both (Egypt) and (Saudi Arabia), as shown in Tables 6 and 7.

Air quality limits in the work environment in Egypt

Table 6 shows the permissible limits for some air pollutants that were measured within the work environment in the gas station according to the Egyptian Labor Law 2003.

Air quality limits in the work environment in Saudi Arabia

Table 7 shows the permissible limits for some air pollutants that were measured within the work environment in the fuel station according OSHA standards.

Table 5. Sources that the researcher relied on in the study.

Egyptian legislation	Saudi legislation
Egyptian Environmental Law. and 1994 update 2009	The General Environment Law and its Executive Regulations 1441-2021
Procedures followed to establish and license a gas station - Ministry of Petroleum	Regulations for fuel, washing and lubrication stations 1406 (Civil Defense)
	List of gas stations and service centers 1435 AH Ministry of Municipal and Rural Affairs
	Guide to provisions and design standards for gas stations (Saudi Industrial Cities and Technology Zones Authority)
	Guide to planning and design standards for gas stations and service centers (Royal Commission for Jubail and Yanbu 1435-2014)
	Facility qualification standards for managing, operating and maintaining gas stations and service centers (Ministry of Petroleum) 1443-2022

Table 6. Air permissible limits for some air pollutants that were measured within the work environment in the two stations according to the Egyptian Labor Law 2003.

Pollutant	Unit	Permissible limit
Total Volatile Organic Compounds (TVOCs)	ppm	N/A
Sulfur dioxide (SO_2)	ppm	2 for 8 hrs., 5 for 15 min.
Carbon monoxide (CO)	ppm	25
Nitrogen monoxide (NO)	ppm	25
Nitrogen dioxide (NO_2)	ppm	3 for 8 hrs., 5 for 15 min.
Particulate Matter Less Than 10 Micrometer (PM_{10})	mg/m^3	3
Particulate Matter Less Than 2.5 Micrometer ($PM_{2.5}$)	mg/m^3	3

Table 7. Air permissible limits for some air pollutants that were measured within the work environment in the two stations according to the (OSHA).

Pollutant	Unit	Permissible limit
Total Volatile Organic Compounds (TVOCs)	ppm	N/A
Sulfur dioxide (SO_2)	ppm	5
Carbon monoxide (CO)	ppm	50
Nitrogen monoxide (NO)	ppm	25
Nitrogen dioxide (NO_2)	ppm	5
Particulate Matter Less Than 10 Micrometer (PM_{10})	mg/m^3	5
Particulate Matter Less Than 2.5 Micrometer ($PM_{2.5}$)	mg/m^3	N/A

Air Pollution Measurements

Total Volatile Organic Compounds (TVOCs)

TVOCs were measured in two fuel stations, one in Egypt and the other in Saudi Arabia, in different sites in each station as shown in Tables 8 & 9, and Figs 5 & 6. For supply area of fuel stations in Saudi Arabia the site has significantly higher TVOCs levels (0.21 ± 0.042) compared to supply area of fuel stations in Egypt (0.025 ± 0.005). Maintenance area TVOCs levels in Saudi Arabia (0.14 ± 0.028) are higher than those in Egypt (0.031 ± 0.006). Laundry area: Saudi Arabia exhibits much higher TVOC levels (0.224 ± 0.045) compared to Egypt (0.021 ± 0.004). Fuel storage area: Saudi Arabia shows higher TVOCs levels (0.14 ± 0.028) compared to Egypt (0.003 ± 0.001). Overall, these comparisons suggest significant differences in TVOCs levels between Saudi Arabia and Egypt across all areas, with Saudi Arabia generally exhibiting higher levels.

Inorganic Gases

Sulfur Dioxide

Sulfur dioxide was measured in the two gasoline fuel stations as shown in Tables 10 & 11 and Figs 7 & 8, and the results showed that all measurements were within the permissible limits and ranged between 0.010 and 0.050 ppm (Egypt), and all measurements were within the permissible limits also and ranged between 0.160 and 0.230 ppm (Saudi Arabia).

Saudi Arabia Fuel Station's supply area (SO_2 = 0.16 ± 0.032) has higher SO_2 levels compared to Egypt Fuel Station's supply area (SO_2 = 0.05 ± 0.010). Saudi Arabia Fuel Station's maintenance area (SO_2 = 0.23 ± 0.046) also demonstrates higher SO_2 levels compared to Egypt Fuel Station's maintenance area (SO_2 = 0.022 ± 0.004). SO_2 levels are higher in Saudi Arabia Fuel Station's laundry area (SO_2 = 0.19 ± 0.038) compared to Egypt Fuel Station's laundry area (SO_2 = 0.018 ± 0.004). Saudi Arabia Fuel Station's fuel storage area (SO_2 = 0.23 ± 0.046) exhibits higher SO_2 levels compared to Egypt Fuel Station's fuel storage area (SO_2 = 0.01 ± 0.002). This analysis provides insights into the variations in SO_2 levels across different areas within fuel stations in both countries.

Table 8. Concentration of TVOCs at various sites inside the working environment of a fuel station in Saudi Arabia.

Saudi Arabia

Site No.	Site Description	Unit	Average	Permissible Levels
S.01	Supply area	TVOCs ppm	0.21±0.042	N/A
S.02	Maintenance area		0.14±0.028	
S.03	Laundry area		0.224±0.045	
S.04	Fuel storage area		0.14±0.028	

N/A: Not available

Table 9. Concentration of TVOCs at various sites inside the working environment of a fuel station in Egypt.

Egypt

Site No.	Site Description	Unit	Average	Permissible Levels
S.01	Supply area	TVOCs ppm	0.025±0.005	N/A
S.02	Maintenance area		0.031±0.006	
S.03	Laundry area		0.021±0.004	
S.04	Fuel storage area		0.003±0.001	

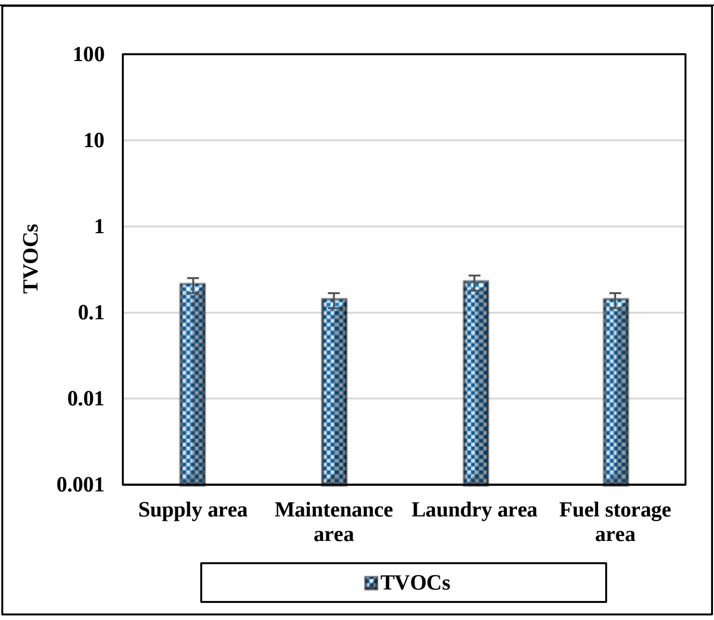

Fig. 5. Concentration of TVOCs at various sites in Saudi Arabia.

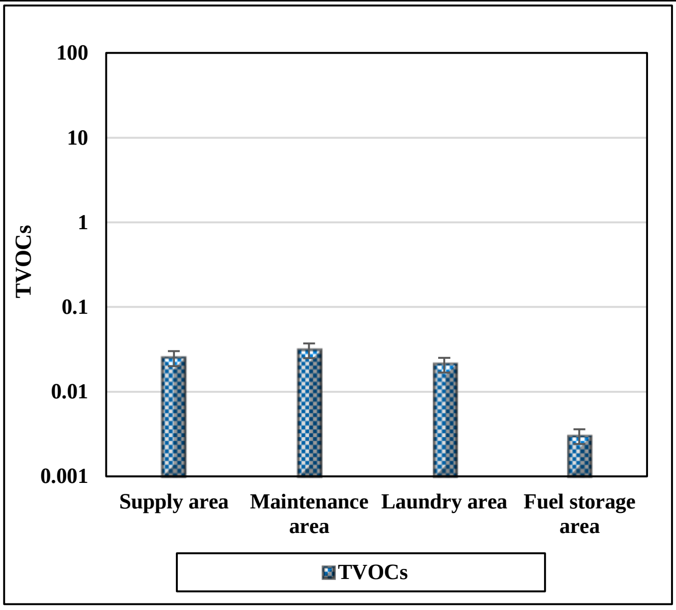

Fig. 6. Concentration of TVOCs at various sites in Egypt.

Analysis of the data

Table 10. Concentration of Sulfur Dioxide at various sites inside the working environment of a fuel station in Saudi Arabia.

Saudi Arabia

Site No.	Site Description	Unit	Average	Permissible Levels
S.01	Supply area	SO_2 ppm	0.16±0.032	5
S.02	Maintenance area		0.23±0.046	
S.03	Laundry area		0.19±0.038	
S.04	Fuel storage area		0.23±0.046	

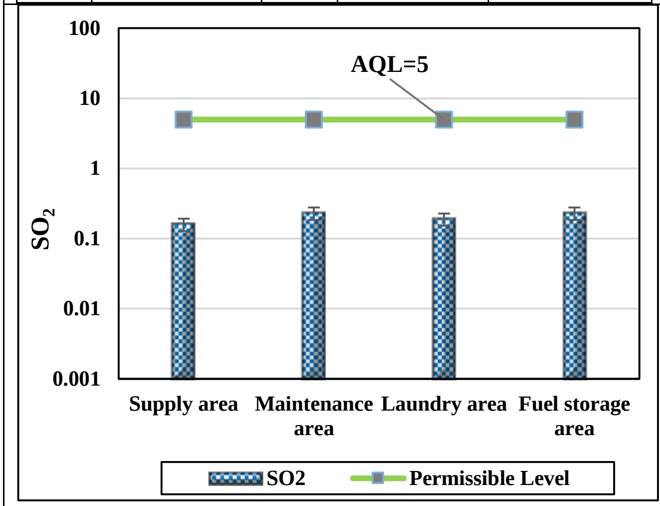

Fig. 7. Concentration of SO_2 at various sites in Saudi Arabia.

Table 11. Concentration of Sulfur Dioxide at various sites inside the working environment of a fuel station in Egypt.

Egypt

Site No.	Site Description	Unit	Average	Permissible Levels
S.01	Supply area	SO_2 ppm	0.05±0.010	2 for 8 hrs. 5 for 15 min
S.02	Maintenance area		0.022±0.004	
S.03	Laundry area		0.018±0.004	
S.04	Fuel storage area		0.01±0.002	

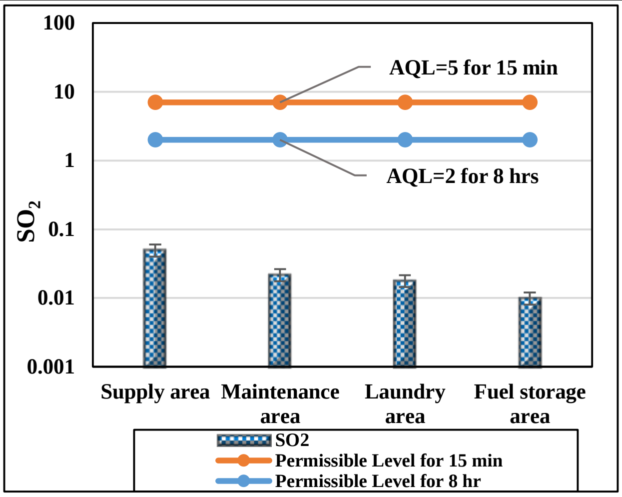

Fig. 8. Concentration of SO_2 at various sites in Egypt.

***AQL: Air quality limit.**

Carbon Monoxide

Carbon monoxide was measured in the two gas stations as shown in Tables 12 & 13 and Figs 9 & 10, and the results showed that all measurements were within the permissible limits and ranged between 2.6 and 6.1 ppm (Egypt), and all measurements were also within the permissible limits and ranged between 2.1 and 4.4 ppm (Saudi Arabia).

Data analysis

Egypt Fuel Station's supply area (CO = 5.5 ± 1.100) exhibits higher CO levels compared to Saudi Arabia Fuel Station's supply area (CO = 2.1 ± 0.420). Egypt Fuel Station's maintenance area (CO = 6.1 ± 1.220) also demonstrates higher CO levels compared to Saudi Arabia Fuel Station's maintenance area (CO = 4.4 ± 0.880). CO levels are higher in Egypt Fuel Station's laundry area (CO = 2.6 ± 0.520) compared to Saudi Arabia Fuel Station's laundry area (CO = 4.3 ± 0.860). CO levels are slightly higher in Egypt Fuel Station's fuel storage area (CO = 3.7 ± 0.740) compared to Saudi Arabia Fuel Station's fuel storage area (CO = 4.1 ± 0.820). This comparison provides insights into the variations in Carbon Monoxide (CO) levels across different areas within fuel stations in both countries.

Table 12. Concentration of CO at various sites inside the working environment of a gas station in Saudi Arabia.

Saudi Arabia

Site No.	Site Description	Unit	Average	Permissible Levels
S.01	Supply area	CO ppm	2.1±0.420	50
S.02	Maintenance area		4.4±0.880	
S.03	Laundry area		4.3±0.860	
S.04	Fuel storage area		4.1±0.820	

Table 13. Concentration of CO at various sites inside the working environment of a gas station in Egypt.

Egypt

Site No.	Site Description	Unit	Average	Permissible Levels
S.01	Supply area	CO ppm	5.5±1.100	25
S.02	Maintenance area		6.1±1.220	
S.03	Laundry area		2.6±0.520	
S.04	Fuel storage area		3.7±0.740	

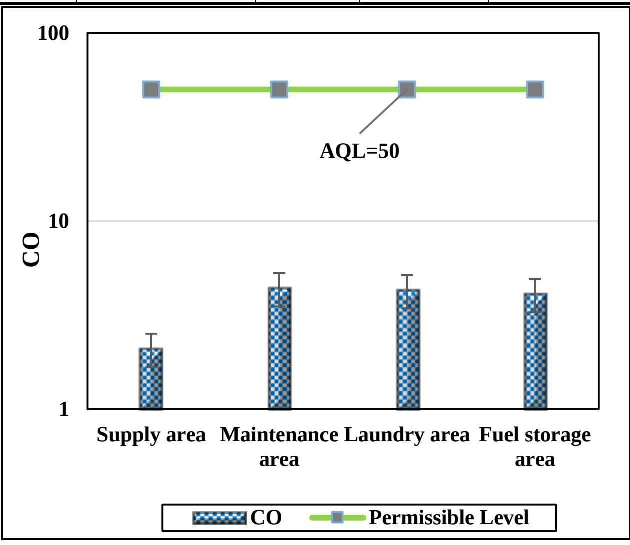

Fig. 9. Concentration of CO at various sites in Saudi Arabia.

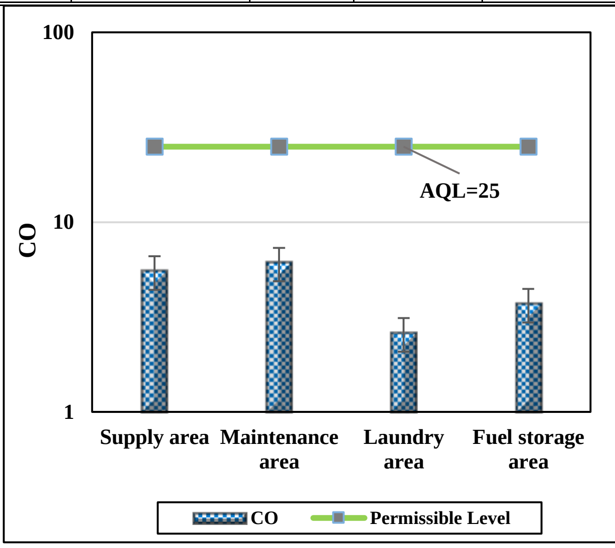

Fig. 10. Concentration of CO at various sites in Egypt.

***AQL: Air quality limit.**

Nitrogen Monoxide

Nitrogen monoxide was measured in two gasoline fuel stations as shown in Tables 14 & 15, and Figs 11 & 12 and the results showed that all measurements were within the permissible limits and ranged between 0.009 and 0.175 ppm (Egypt), and all measurements were also within the permissible limits and ranged between 0.2 and 0.4 ppm (Saudi Arabia).

Data analysis

Saudi Arabia Fuel Station's supply area (NO = 0.4 ± 0.080) exhibits higher NO levels compared to Egypt Fuel Station's supply area (NO = 0.132 ± 0.026). Saudi Arabia Fuel Station's maintenance area (NO = 0.3 ± 0.060) also demonstrates higher NO levels compared to Egypt Fuel Station's maintenance area (NO = 0.132 ± 0.026). NO levels are higher in Saudi Arabia Fuel Station's laundry area (NO = 0.2 ± 0.040) compared to Egypt Fuel Station's laundry area (NO = 0.112 ± 0.022). NO levels are significantly higher in Saudi Arabia Fuel Station's fuel storage area (NO = 0.3 ± 0.060) compared to Egypt Fuel Station's fuel storage area (NO = 0.009 ± 0.002). This comparison highlights the variations in Nitrogen Monoxide (NO) levels across different areas within fuel stations in both countries.

Table 14. Concentration of NO at various sites inside the working environment of a gas station in Saudi Arabia.

Saudi Arabia

Site No.	Site Description	Unit	Average	Permissible Levels
S.01	Supply area	NO ppm	0.4±0.080	25
S.02	Maintenance area		0.3±0.060	
S.03	Laundry area		0.2±0.040	
S.04	Fuel storage area		0.3±0.060	

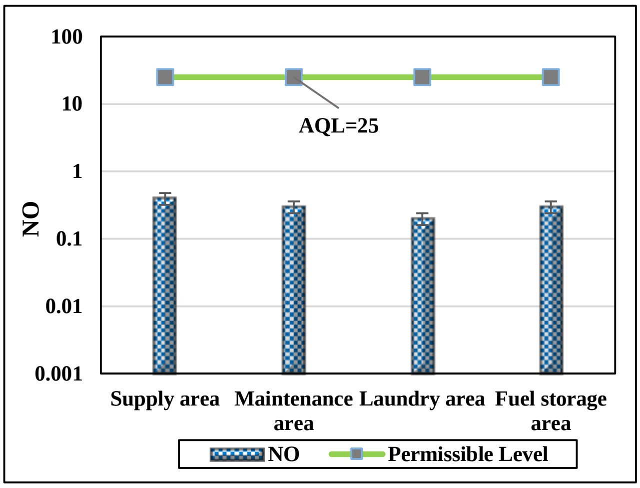

Fig. 11. Concentration of NO at various sites in Saudi Arabia.

Table 15. Concentration of NO at various sites inside the working environment of a gas station in Egypt.

Egypt

Site No.	Site Description	Unit	Average	Permissible Levels
S.01	Supply area	NO ppm	0.132±0.026	25
S.02	Maintenance area		0.132±0.026	
S.03	Laundry area		0.112±0.022	
S.04	Fuel storage area		0.009±0.002	

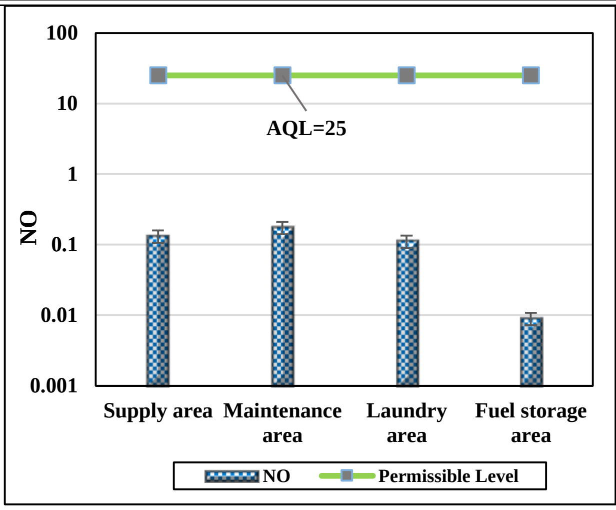

Fig. 12. Concentration of NO at various sites in Egypt.

***AQL: Air quality limit.**

Nitrogen Dioxide

Nitrogen dioxide was measured in two gasoline fuel stations as shown in Tables 16 & 17, and Figs 13 & 14 and the results showed that all measurements were within the permissible limits and ranged between 0.013 and 0.77 ppm (Egypt), and all measurements were within the permissible limits also, and ranged between 0.004 and 0.008 ppm (Saudi Arabia).

Data analysis

Egypt Fuel Station's supply area (NO_2 = 0.059 ± 0.012) exhibits significantly higher NO_2 levels compared to Saudi Arabia Fuel Station's supply area (NO_2 = 0.008 ± 0.002). Egypt Fuel Station's maintenance area (NO_2 = 0.077 ± 0.015) also demonstrates higher NO_2 levels compared to Saudi Arabia Fuel Station's maintenance area (NO_2 = 0.007 ± 0.001). NO_2 levels are higher in Egypt Fuel Station's laundry area (NO_2 = 0.061 ± 0.012) compared to Saudi Arabia Fuel Station's laundry area (NO_2 = 0.004 ± 0.001). NO_2 levels are significantly higher in Egypt Fuel Station's fuel storage area (NO_2 = 0.013 ± 0.003) compared to Saudi Arabia Fuel Station's fuel storage area (NO_2 = 0.006 ± 0.001. This comparison reveals notable differences in Nitrogen Dioxide (NO_2) levels across different areas within fuel stations in both countries.

Particulate Matter

a) Particulate Matter Less Than 10 Micrometers (PM_{10})

PM_{10} was measured in the two gasoline fuel stations as shown in Tables 18 & 19 and Figs 15 & 16, and the results showed that all measurements were within the permissible limits and ranged between 0.030 and 0.327 mg/m^3 (Egypt), and all measurements were within the permissible limits also, and ranged between 0.110 and 0.208 mg/m^3 (Saudi Arabia).

Analyze and compare the data based on the specific areas within the fuel stations: Supply area: Egypt Fuel Station (PM_{10} = 0.327 ± 0.065) has substantially higher PM_{10} levels compared to Saudi Arabia Fuel Station (PM_{10} = 0.208 ± 0.042).
Maintenance area: Egypt Fuel Station (PM_{10} = 0.187 ± 0.037) also demonstrates higher PM_{10} levels compared to Saudi Arabia Fuel Station (PM_{10} = 0.158 ± 0.032).

b) Particulate Matter Less Than 2.5 Micrometers ($PM_{2.5}$)

$PM_{2.5}$ was measured in the two gasoline fuel stations as shown in Tables 20 & 21 and Figs 17 & 18, and the results showed that all measurements were within the permissible limits and ranged between 0.061 and 0.152 mg/m^3 (Egypt), and all measurements were low and ranged between 0.079 and 0.94 mg/m^3 (Saudi Arabia), “Note: Saudi Arabia has no permitted limits for $PM_{2.5}$”.

Table 16. Concentration of NO_2 at various sites nside the working environment of a gas station in Saudi Arabia.

Saudi Arabia				
Site No.	**Site Description**	**Unit**	**Average**	**Permissible Levels**
S.01	Supply area	NO_2 ppm	0.008±0.002	5
S.02	Maintenance area		0.007±0.001	
S.03	Laundry area		0.004±0.001	
S.04	Fuel storage area		0.006±0.001	

Table 17. Concentration of NO_2 at various sites inside the working environment of a gas station in Egypt.

Egypt				
Site No.	**Site Description**	**Unit**	**Average**	Permissible Levels
S.01	Supply area	NO_2 ppm	0.059±0.012	3 for 8 hrs. 5 for 15 min.
S.02	Maintenance area		0.077±0.015	
S.03	Laundry area		0.061±0.012	
S.04	Fuel storage area		0.013±0.003	

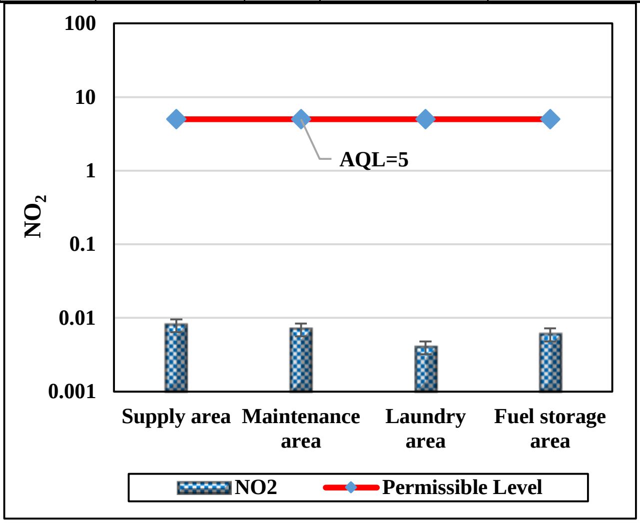

Fig. 13. Concentration of NO_2 at various sites in Saudi Arabia.

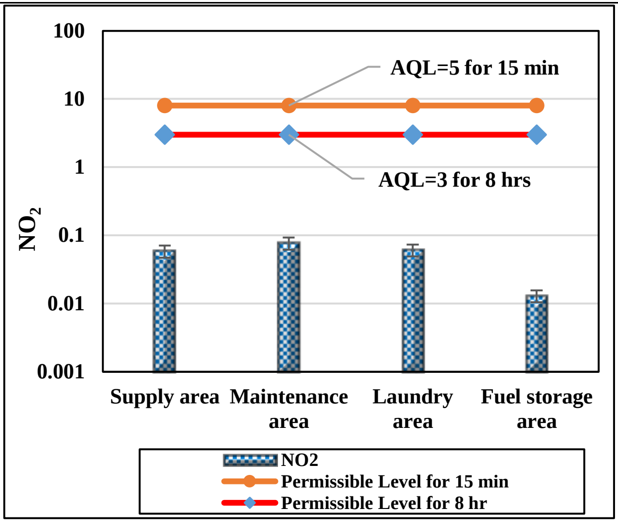

Fig. 14. Concentration of NO_2 at various sites in Egypt.

***AQL: Air quality limit.**

Analyze and compare the data based on the specific areas within the fuel stations: Supply area: Egypt Fuel Station ($PM_{2.5}$ = 0.152 ± 0.030) has higher $PM_{2.5}$ levels compared to Saudi Arabia Fuel Station ($PM_{2.5}$ = 0.094 ± 0.019). Maintenance area: Egypt Fuel Station ($PM_{2.5}$ = 0.085 ± 0.017) also demonstrates higher $PM_{2.5}$ levels compared to Saudi Arabia Fuel Station ($PM_{2.5}$ = 0.079 ± 0.016). Laundry area: $PM_{2.5}$ levels are higher in Egypt Fuel Station ($PM_{2.5}$ = 0.072 ± 0.014) compared to Saudi Arabia Fuel Station ($PM_{2.5}$ = 0.082 ± 0.016). Fuel storage area: Egypt Fuel Station ($PM_{2.5}$ = 0.061 ± 0.012) exhibits slightly lower $PM_{2.5}$ levels compared to Saudi Arabia Fuel Station ($PM_{2.5}$ = 0.081 ± 0.016).

Table 18. Concentration of PM_{10} at various sites inside the working environment of a gas station in Saudi Arabia.

Saudi Arabia

Site No.	Site Description	Unit	Average	Permissible Levels
S.01	Supply area	PM_{10} mg/m^3	0.208±0.042	5
S.02	Maintenance area		0.158±0.032	
S.03	Laundry area		0.118±0.024	
S.04	Fuel storage area		0.11±0.022	

Table 19. Concentration of PM_{10} at various sites inside the working environment of a gas station in Egypt.

Egypt

Site No.	Site Description	Unit	Average	Permissible Levels
S.01	Supply area	PM_{10} mg/m^3	0.327±0.065	3
S.02	Maintenance area		0.187±0.037	
S.03	Laundry area		0.234±0.047	
S.04	Fuel storage area		0.030±0.006	

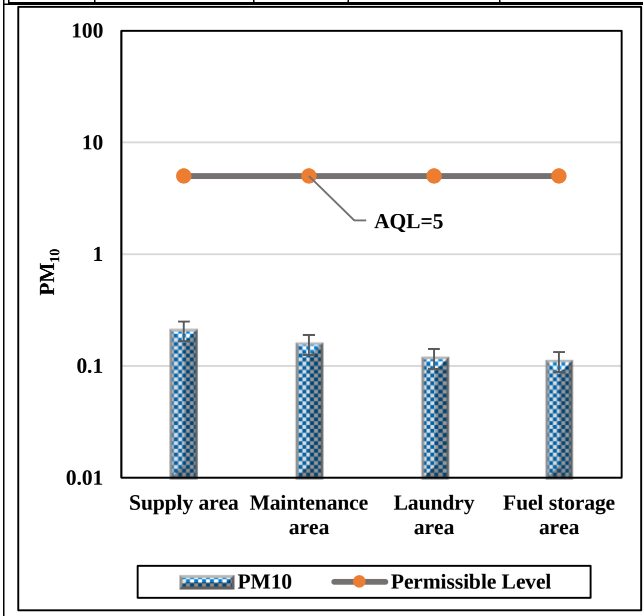

Fig. 15. Concentration of PM_{10} at various sites in Saudi Arabia.

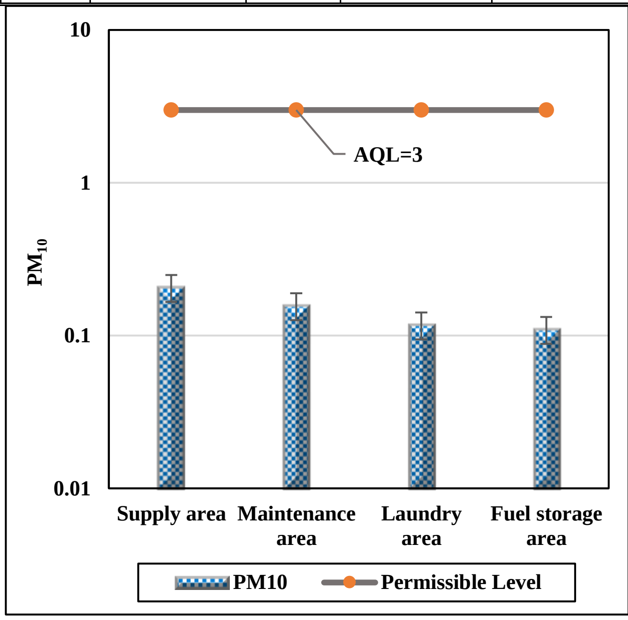

Fig. 16. Concentration of PM_{10} at various sites in Egypt.

***AQL: Air quality limit.**

c) Correlation between Particulate Matter Less Than 10 Micrometers (PM_{10}) and Particulate Matter Less Than 2.5 Micrometers ($PM_{2.5}$)

1. In Egypt

The correlation between PM_{10} and $PM_{2.5}$ in different areas in fuel stations in Egypt is 0.81 indicates a strong positive correlation between the levels of PM_{10} (particulate matter with a diameter of 10 micrometers or less) and $PM_{2.5}$ (particulate matter with a diameter of 2.5 micrometers or less) in various locations within fuel stations in Egypt (Fig. 19).

Table 20. Concentration of $PM_{2.5}$ at various sites inside the working environment of a gas station in Saudi Arabia.

Table 21. Concentration of $PM_{2.5}$ at various sites inside the working environment of a gas station in Egypt.

Saudi Arabia

Site No.	Site Description	Unit	Average	Permissible Levels
S.01	Supply area	$PM_{2.5}$ mg/m^3	0.094±0.019	N/A
S.02	Maintenance area		0.079±0.016	
S.03	Laundry area		0.082±0.016	
S.04	Fuel storage area		0.081±0.016	

Egypt

Site No.	Site Description	Unit	Average	Permissible Levels
S.01	Supply area	$PM_{2.5}$ mg/m^3	0.152±0.030	3
S.02	Maintenance area		0.085±0.017	
S.03	Laundry area		0.072±0.014	
S.04	Fuel storage area		0.061±0.012	

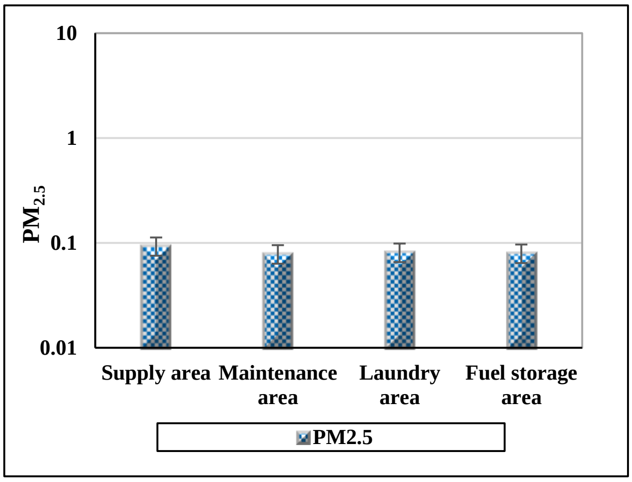

Fig. 17. Concentration of $PM_{2.5}$ at various sites in Saudi Arabia.

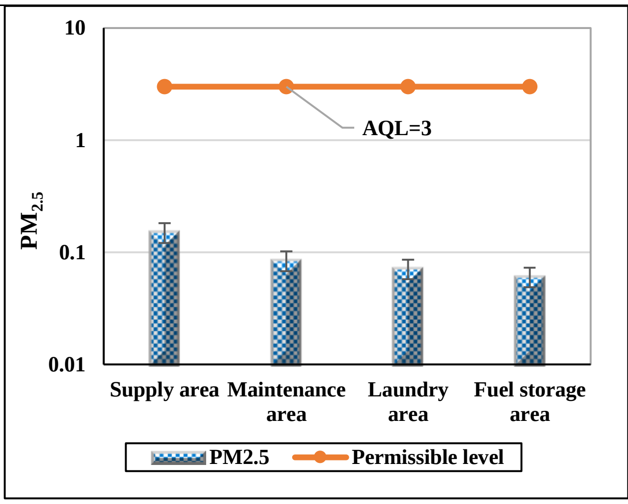

Fig. 18. Concentration of $PM_{2.5}$ at various sites in Egypt.

***AQL: Air quality limit.**

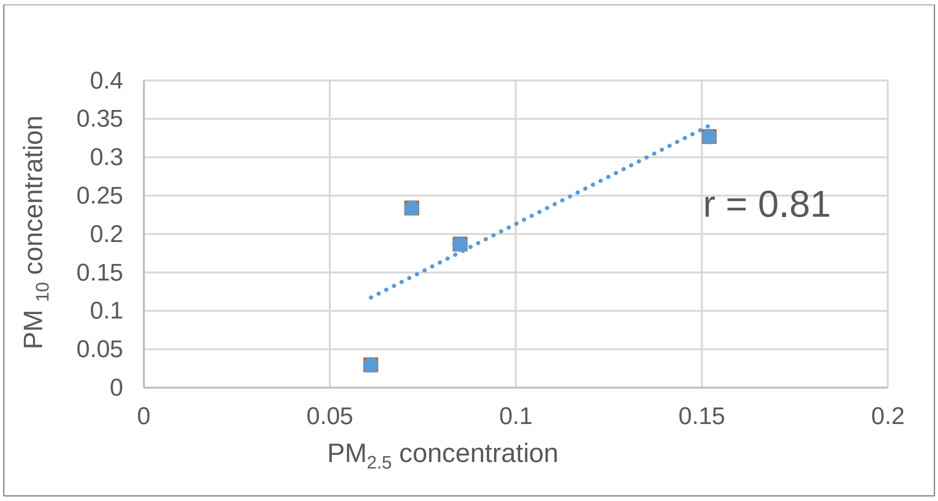

Fig. 19. Correlation between (PM_{10}) and ($PM_{2.5}$) in the fuel station in Egypt.

2. In Saudi Arabia

The correlation between PM_{10} and $PM_{2.5}$ in different areas in fuel stations in Saudi Arabia is 0.79 means that there is a strong positive correlation between the levels of PM_{10} and $PM_{2.5}$ in various locations within fuel stations in Saudi Arabia (Fig. 20).

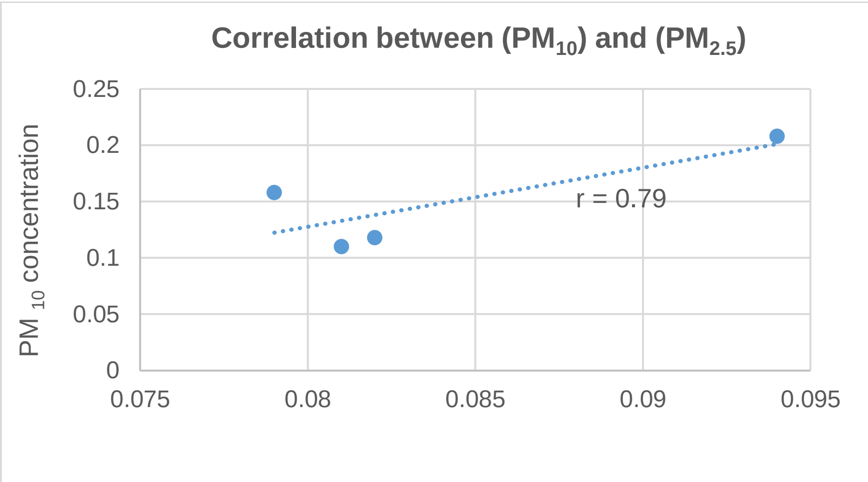

Fig. 20. Correlation between (PM_{10}) and ($PM_{2.5}$) in the fuel station in Saudi Arabia.

Noise Levels

Noise was measured in the two gasoline fuel stations as shown in Tables 22 & 23, and Figs 21 & 22 and the results showed that all measurements were within the permissible limits and ranged between 61.5 and 81.6 dB (Egypt), and all measurements were within the permissible limits also and ranged between 65.2 and 72.1 dB (Saudi Arabia).

Data analysis

Egypt Fuel Station's supply area (Noise Level = 0.152 ± 0.030) exhibits higher noise levels compared to Saudi Arabia Fuel Station's supply area (Noise Level = 0.094 ± 0.019). Egypt Fuel Station's maintenance area (Noise Level = 0.085 ± 0.017) also demonstrates higher noise levels compared to Saudi Arabia Fuel Station's maintenance area (Noise Level = 0.079 ± 0.016). Noise levels are higher in Egypt Fuel Station's laundry area (Noise Level = 0.072 ± 0.014) compared to Saudi Arabia Fuel Station's laundry area (Noise Level = 0.082 ± 0.016). Noise levels are higher in Egypt Fuel Station's fuel storage area (Noise Level = 0.061 ± 0.012) compared to Saudi Arabia Fuel Station's fuel storage area (Noise Level = 0.081 ± 0.016). This comparison highlights the differences in noise levels across different areas within fuel stations in both countries.

Table 22. Concentration of Noise at various sites inside the working environment of a gas station in Saudi Arabia.

Saudi Arabia

Site No.	Site Description	Unit	Average	Permissible Levels
S.01	Supply area	dB	65.2±3.3	90
S.02	Maintenance area		68.0±3.4	
S.03	Laundry area		72.1±3.6	
S.04	Fuel storage area		66.0±3.3	

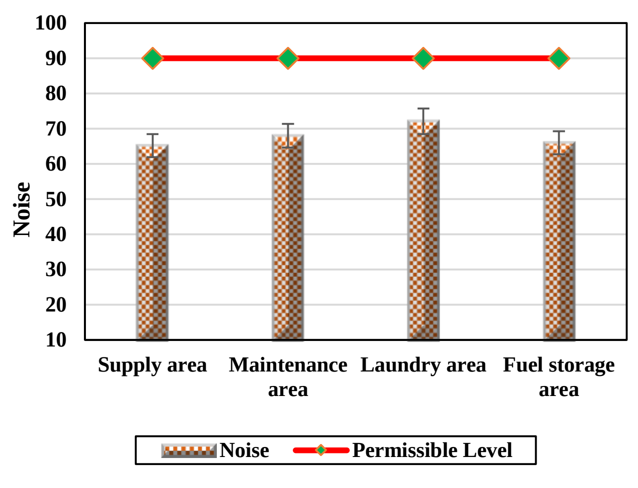

Fig. 21. Levels of Noise at various sites in Saudi Arabia.

Table 23. Concentration of Noise at various sites inside the working environment of a gas station in Egypt .

Egypt

Site No.	Site Description	Unit	Average	Permissible Levels
S.01	Supply area	dB	61.5±3.1	90
S.02	Maintenance area		81.6±4.1	
S.03	Laundry area		75.3±3.8	
S.04	Fuel storage area		62.3±3.1	

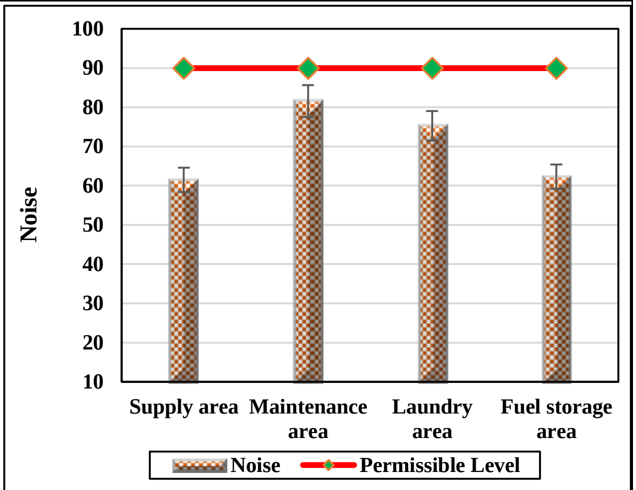

Fig.22. Levels of Noise at various sites in Egypt.

The results of this study were below the allowable limits in both countries. However, caution should always be exercised at fuel stations because all measured variable factors pose a significant risk if they exceed the permissible limits or increase with continuous exposure for station workers. We can clarify the most important health and environmental effects as follows:

In case of increase in (TVOCs) (Eisaei et al., 2015)

Health effects

- Health consequences may include irritation of the eyes, nose, and throat, headaches, loss of coordination, and nausea. Damage to the liver, kidneys, and central nervous system. Some organics can cause cancer in animals, while others are suspected or shown to cause cancer in humans.
- Common symptoms of VOC exposure include conjunctival irritation, nose and throat pain, headache, allergic skin response, dyspnea, decreases in serum cholinesterase levels, nausea, emesis, epistaxis, exhaustion, and dizziness. Eye and respiratory tract discomfort, vision disturbances, and memory loss.

In case of increase in Sulfur Dioxide (SO_2) (Environmental Protection Agency, 31 January, 2024)
Health effects

- Short-term exposure to SO_2 can damage the respiratory system and make breathing difficult. Children, the elderly, and those suffering from asthma are most vulnerable to the effects of SO_2.
- High SO_2 emissions can result in the creation of additional sulfur oxides (SO_x). SO_x can react with other substances in the atmosphere, forming tiny particles. These particles contribute to particulate matter (PM) pollution, which can penetrate deeply into sensitive areas of the lungs and create further health issues.

Environmental effects

- High amounts of gaseous SO_x can damage trees and plants by destroying leaves and reducing growth.
- SO_2 and other SO_x can cause acid rain, which harms vulnerable ecosystems.
- SO_2 and other SO_x react with other substances in the environment to create tiny particles, reducing visibility (haze).

In case of increase in Carbon Monoxide (Environmental Protection Agency, 13 July 2023)
Health effects

- High CO levels in the air limit oxygen delivery to vital organs such as the heart and brain. High quantities of CO in confined spaces can induce dizziness, disorientation, coma, and even death.
- High quantities of CO are unlikely to occur outdoors. However, increased CO levels outside might be especially concerning for patients with certain forms of cardiac problems. These persons already have a diminished ability to deliver oxygenated blood to their hearts in instances when the heart requires more oxygen than normal. They are particularly susceptible to the effects of CO when exercising or under stress. In certain cases, short-term exposure to increased CO levels may result in decreased oxygen to the heart, accompanied by chest discomfort known as angina.

In case of increase in Nitrogen Dioxide (Environmental Protection Agency, 25 July, 2023)
Health effects

- Inhaling air with a high NO_2 concentration might irritate the air passageways in the human respiratory system. Even short-term exposures might worsen respiratory disorders, notably asthma, causing symptoms such as coughing, wheezing, or trouble breathing. This can result in hospitalizations and trips to emergency rooms.
- Prolonged exposure to high NO_2 levels may lead to the development of asthma and increase vulnerability to respiratory infections.

- Asthmatics, children, and the elderly are particularly sensitive to the health effects of NO_2.
- NO_2, like other nitrogen oxides (NO_x), combines with a variety of chemicals in the environment, producing particulate matter and ozone. Both of these chemicals are toxic when breathed, creating negative effects on the respiratory system.

Environmental effects

- NO_2 and other NO_x react with water, O_2, and other molecules in the atmosphere to produce acid rain, which affects delicate ecosystems.
- However, the nitrate particles produced by NO_x haze the air and make visibility difficult. This has an impact on the various national parks that we visit for their scenic views, NO_x in the atmosphere causes nutrient contamination in coastal seas.

In case of increase in PM_{10} and $PM_{2.5}$ (Environmental Protection Agency, 23 August 2023)

Health effects

- Exposure to these particles can harm your lungs and heart. Numerous scientific studies have linked particle pollution exposure to a variety of problems, including premature death in people with heart or lung disease, nonfatal heart attacks, irregular heartbeat, aggravated asthma, reduced lung function, and increased respiratory symptoms such as airway irritation, coughing, or difficulty breathing.
- People with heart or lung illnesses, children, and the elderly are especially vulnerable to particle pollution exposure.

Environmental effects

- Visibility impairment: PM is the main cause of reduced visibility (haze).
- Environmental damage: PM may travel large distances by wind and settle on land or water. Depending on their chemical composition, the effects of this settling may include acidifying lakes and streams, altering the nutrient balance in coastal waters and large river basins, depleting nutrients in soil, harming sensitive forests and farm crops, affecting ecosystem diversity, and contributing to acid rain effects.
- Material damage: PM may discolor and harm stone and other materials, especially culturally significant things like sculptures and monuments.

In case of increase in Noise Levels (Australian Academy of Science, 4 February 2016).

Health effects

- Headaches and migraines are the most prevalent short-term effects of noise pollution. Constant noise can cause terrible headaches, making it difficult for some people to focus. Migraine symptoms may include light sensitivity and nausea. Noise pollution can cause stress both in the short and long term.
- Hearing loss: Hearing loss happens when components in the inner ear are destroyed, which can happen when sounds reach or surpass 85 dB.

- Noise pollution exceeding 45 decibels wakes up most individuals, although disturbances at lower decibel levels may disturb light sleepers. A lack of sleep can cause a variety of health issues, including weariness, irritability, loss of focus, and even a compromised immune system.
- Hypertension: Regular exposure to noise pollution has been linked to higher blood pressure levels. This might be due to adrenaline or stress from interruptions.
- Stroke: This was especially more apparent in individuals over the age of 65

Environmental effects

- Anthropogenic noise pollution affects animals in many settings.
- Animals change their behavior or relocate to avoid loud locations.
- Changes in animal behavior can affect entire ecosystems.

These results are consistent with the results conducted in Lahore **(Tabinda et al., 2019)** declared that SO_2 concentrations in gasoline station in Lahore, Pakistan had concentrations ranging from 0.4117 to 0.892 ppm, CO concentrations ranged from 5.067 to 8.294, NO concentrations ranged from 0.1474 to 0.2282 ppm, NO_2 concentrations ranged from 0.0324 to 0.0608 ppm, and PM_{10} concentrations ranged from 0.341 to 0.415 mg/m^3, $PM_{2.5}$ concentrations ranged from 0.176 to 0.275 mg/m^3, and noise levels ranged from 75.15 to 79.76 dB, while these results are not consistent with the study that was conducted in Iran (Tehran) on the concentration of volatile organic compounds at six fuel stations, whose results were higher than the World Health Organization guidelines **(Eisaei et al., 2015)** and ranged from 434.24 to 859.78 ppm.

In Saudi Arabia and Egypt, petrol-filling staff are employed rather than self-serviced, enhancing opportunities for exposure. Long-term exposure to petrol vapor has been proven to damage several physiological systems in the body. Cohort studies indicate that exposure to air pollution is linked to respiratory and cardiovascular disorders, as well as lung cancer **(Dockery et al.,1993)**. According to WHO **(World Health Organization, 2000)**, continuous exposure by inhalation and handling may pose a serious occupational hazard in such distribution facilities. As a result, it is critical to screen air at the workplace for the presence of aromatic hydrocarbons and other pollutants such as CO, NOx, and PM **(Begum & Rathna, 2012; Basahi et al., 2015)**.

Soil Pollution Measurements

1- Benzene, Toluene, Ethylbenzene, and Xylene (BTEX)

Benzene, toluene, ethylbenzene, and xylene (BTEX) were measured in the soil sample of the gas station in Saudi Arabia and the results indicated that there was no contamination in the soil and results were within the permissible limits according to the standards of the National Center for Control of Environmental Compliance (NCEC) as shown in Table 24.

Table 24. Concentration of benzene, toluene, ethylbenzene, and xylene in the soil inside the working environment of a gas station in Saudi Arabia**.**

Test Name	Result	Units	Methods	NCEC Standards
Benzene	< 0.001	mg/kg	APHA 8260	< 0.078
Toluene	< 0.001			< 0.120
Ethylbenzene	< 0.001			< 0.120
Xylene	< 0.001			< 1.90

2- Total Petroleum Hydrocarbons (TPHs) Fraction Analysis

Total Petroleum Hydrocarbons (TPHs) were measured in the soil and the results indicated that there was no pollution in the soil and that they fell within the permissible limits according to the standards of the National Center for Oversight of Environmental Compliance as shown in Table 25.

Hilpert et al. (2015) explained the harmful effects of fuel leakage into the soil as follows: In addition to coming into contact with surface-level gasoline fumes, fuel leaks can lead to other exposure routes. Fuel stations frequently have contaminated soil and groundwater. Well users may be exposed to benzene and other pollutants if drinking water wells near fuel stations become contaminated. In rural regions, these wells are sometimes the only sources of potable water. Furthermore, hydrocarbons that have spilled during rainy or other weather events can contaminate surface waters through runoff. People who use surface waters for recreational or other reasons may come into contact with these toxins by accidental ingestion or cutaneous contact.

Table 25. Concentration of Total Petroleum Hydrocarbons (TPHs) in the soil inside the working environment of a gas station in Saudi Arabia.

Test Name	Result	Units	Methods	NCEC Standards	MDL*
$C_6 - C_{10}$ Fraction	< 2.30	mg/kg	APHA 8260/8015 B	< 440.00	2.30
$C_{10} - C_{16}$ Fraction	< 2.30		APHA 8015 B	< 520.00	
$C_{16} - C_{34}$ Fraction	< 2.30			< 3400.00	
$C_{34} - C_{50}$ Fraction	15.68			< 6600.00	

*MDL: min. Detection Limit

To preserve the environment surrounding fuel stations; **(Wu et al., 2017)** recommended installing secondary containment measures like double-layer tanks or impermeable ponds for oil storage. Urgent actions include investigating gas station leakage, issuing and enforcing precise regulations, and enhancing supervision. Replacing single-layer steel tanks with double-layer ones and prioritizing pond construction based on risk ranking are crucial steps. Strengthening groundwater monitoring, supervision, laws, regulations, and pollution remediation efforts are also essential for effective control.

Conclusion and Recommendations

All measured air pollutants (total volatile organic compounds (TVOCs), sulfur dioxide (SO_2), carbon monoxide (CO), nitrogen monoxide (NO), nitrogen dioxide (NO_2), particulate matter less than 10 micrometer (PM_{10}), particulate matter less than 2.5 micrometer ($pm_{2.5}$), and noise were within the permissible limits of EEAA (Egypt) and NCEC (Saudi Arabia). Measured soil pollutants (benzene, toluene, ethylbenzene, xylene (BTEX), and total petroleum hydrocarbons (TPH)) also were the permissible limits of NCEC (Saudi Arabia).

Several recommendations are suggested for more improvement:

- Conduct a periodic evaluation and monitoring by the relevant government agencies of fuel stations and link this evaluation to percentages. Based on these percentages, the licenses granted to the stations are renewed or cancelled.
- Increase the awareness of workers through preparation, qualification, and training on different tasks they perform at fuel stations.
- Periodical monitoring and measuring volatile vapors from fuel tanks and taking preventive measures that ensure environmental protection.

These recommendations could enhance protecting the rights of neighbors and citizens, recognizing their right to enjoy a healthy and sustainable environment, providing a suitable environment for neighbors to live in dignity, and providing the necessary minimum level of air quality.

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