Research Article

Assessment of the air quality levels in the King Abdul Aziz Port in Dammam

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Abstract

Background: Shipping transportation, loading and uploading, is considered a major source of air pollution worldwide. All the recent studies are concerned with the serious impacts of air pollutants, but, in ports, ship emissions still have a significant deterioration on the air quality levels on a local and regional scale. In ports, the main air pollutants resulting from the ship exhaust emissions are carbon dioxide (CO_2), sulfur dioxide (SO_2), nitrogen oxides (NO_x), carbon monoxide (CO), particulate matter (PM), and volatile organic compounds (VOCs). The significant health effects of the air pollutants emitted from the industrial activities in ports may include respiratory diseases, cardiovascular disease, lung cancer, and death.

Objective: To assess the air quality levels in the King Abdul Aziz Port in the eastern region of Saudi Arabia for compliance with national and international standards.

Materials and Methods: This study was conducted at the King Abdul Aziz Port where four stations were analyzed for gaseous and particulate air pollutants using certified and calibrated equipment.

Result: In comparison with the Recommended Saudi and International Air Quality Guidelines, the concentration levels of NO_2, SO_2, O3, and VOCs and the levels of PM_{10} surprisingly exceeded the limit in all the sampling stations in the port, while low levels of CO and CO_2 were detected in all the sampling stations.

Conclusion: Air quality parameters such as NO_2, SO_2, O_3, VOCs, PM_{10} were in high significant concentrations from all the stations, especially in cargo loading and unloading platforms and traffic activities. However, further studies are urgently needed to carry out air pollution investigations of the sea port in the kingdom.

KEY WORDS: Port, air quality, Dammam, pollution, shipping transportation

Introduction

Shipping transportation, loading, and uploading are considered a major source of air pollution worldwide. All the recent studies are concerned with the serious impacts of air pollutants, but, in ports, ship emissions still have a significant deterioration on the air quality levels on a local and regional scale.[1]

In the King Abdul Aziz Port (KAP), in ports, the main air pollutants resulting from the ship exhaust emissions are carbon dioxide (CO_2), sulfur dioxide (SO_2), nitrogen oxides (NO_x), carbon monoxide (CO), particulate matter (PM), and volatile organic compounds (VOCs). The significant health effects of air pollutants emitted from the industrial activities in ports may include respiratory diseases, cardiovascular disease, lung cancer, and death.[2,3]

Outdoor air pollution control strategy is remaining a major problem in the developing countries. Data from the different air quality guidelines agencies found that the air quality in large industrial cities is remarkably poor, and large sectors of people in those countries are exposed to ambient concentrations

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of air pollutants, which significantly exceeds the air quality guidelines.[4,5]

As the KAP is located in the Eastern province area, which is considered as a high zone of industrial activities, and the air quality condition is related to different air pollutants emitted from shipping, industries, and vehicles. Moreover, the KAP represents a major source of serious air pollutants that have adverse ill-health to nearby communities and deterioration of regional air pollution problems. This study aimed to assess the air quality levels in the KAP in the eastern region of Saudi Arabia for compliance with the national and international standards.

Materials and Methods

This study was conducted at the KAP where four sampling stations were selected randomly for the purpose of measurement of the gaseous and PM air pollutants as shown in Figure 1.

- Station 1: Main gate
- Station 2: Gate I (platforms 23–35)
- Station 3: Gate II (platforms 1–9)
- Station 4: Gate III (platforms 14–22)

This study was conducted between February and May 2014. The measurements were conducted twice a week, mainly on Monday and Thursday.

Gaseous air pollutants measurements

The concentrations of gaseous air pollutants such as VOCs, CO and CO_2 were measured using air quality monitors equipment. However, NO_2, SO_2, and O_3 were analyzed by using the GrayWolf Direct Sense Monitoring Kit. Thirty samples were taken in each station for the different air pollutants.

Particulate sampling (PM_{10})

Personal dust samplers were used to analyze the PM_{10}. The level of PM was determined gravimetrically in microgram of dust per cubic meter of air. Forty dust samples were collected in every station.

Meteorological factors measurements

Wind speed, temperature, and relative humidity are the major factors that modify the air quality monitoring methodology.

Statistical analysis

All the data were tested and graphically presented by using SPSS and Excel statistical applications, where descriptive statistics, independent *t*-test, and ANOVA test were used.

Result

Table 1 shows the mean levels of air quality levels in the KAP, where the levels of No_2, SO_2, O_3, and VOCs were higher than the permissible exposure limits and Saudi air quality guidelines [Table 2]. However, the levels of CO and CO_2 were below the Saudi air quality guidelines, and these reflect the impact of the ship emissions and the effect of trucks traffic around the port.

In Table 3, in comparison of the air quality levels between the main gate and gate I, there was a significant association in the levels of CO, NO_2, SO_2, O_3, PM_{10}, and VOCs ($P < 0.01$). However, there was no significant association in the levels of CO_2 ($P > 0.05$). In Table 4, in comparison with the air quality levels between the gates I and II, there was a significant difference/association in the levels of CO_2 and SO_2 ($P < 0.01$). However, there was no significant association in the levels of NO_2, CO_2, PM_{10}, O_3, and VOCs ($P > 0.05$).

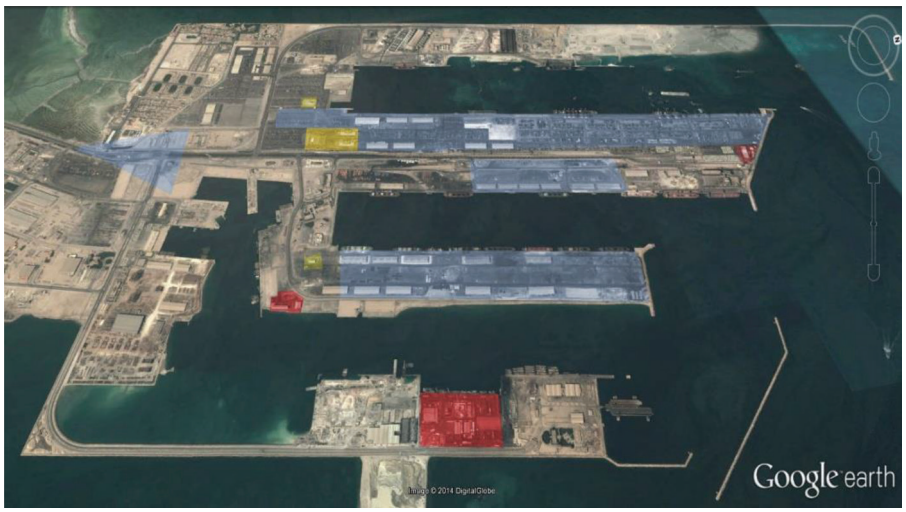

Figure 1: Air quality monitoring sites.

Table 1: The mean levels of air quality levels in the King Abdul Aziz Port

	CO, ppm	NO_2, ppm	CO_2, ppm	SO_2, ppm	PM_{10}, $\mu g/m^3$	O_3, ppm	VOCs, ppm
Main gate	3.778	1.3.37	965.00	1.878	338.67	0.940	0.73
Gate I	5.833	2.133	1082.00	4.833	229.50	0.85	0.90
Gate II	3.111	1.900	659.56	4.667	223.00	0.651	0.84
Gate III	0.478	0.904	696.67	2.922	622.78	0.351	0.71

Table 2: Saudi air quality guidelines

Pollutant type	Saudi TLV
O_3	0.1 ppm
VOCs	0.1 ppm
SO_2	0.169 ppm
NO_2	0.35 ppm
PM_{10}	150 mg/m^3
CO	9 ppm
CO_2	1,500 ppm

Table 3: ANOVA comparison between the mean air quality levels in King Abdul Aziz Port

	Main gate						
	CO, ppm	NO_2, ppm	CO_2, ppm	SO_2, ppm	PM_{10}, $\mu g/m^3$	O_3, ppm	VOCs, ppm
Gate I	0.010	0.250	0.033	0.006	0.001	0.070	0.005
Gate II	0.350	0.020	0.233	0.004	0.797	0.340	0.061
Gate III	0.060	0.005	0.002	0.288	0.722	0.007	0.109

Gate I, 23–35; gate II, 1–9; gate III, 14–22.

Table 4: ANOVA comparison between the mean air quality levels in the King Abdul Aziz Port

	Gate I						
	CO, ppm	NO_2, ppm	CO_2, ppm	SO_2, ppm	PM_{10}, $\mu g/m^3$	O_3, ppm	VOCs, ppm
Gate II	0.002	0.001	0.263	0.867	0.001	0.912	0.201
Gate III	0.001	0.001	0.397	0.004	0.001	0.001	0.127

Gate I, 23–35; gate II, 1–9; gate III, 14–22.

Table 5: ANOVA comparison between the mean air quality levels in the King Abdul Aziz Port

	Gate II					
	CO_2, ppm	NO_2, ppm	SO_2, ppm	PM_{10}, $\mu g/m^3$	O_3, ppm	VOCs, ppm
Gate III	0.681	0.033	0.007	0.922	0.001	0.772

Table 6: The mean levels of the meteorological factors in the different selected areas in the King Abdul Aziz Port

	Temperature°C	Relative humidity	Wind speed
Main gate	30.2 ± 2.7	56.2 ± 17.2	17.04 ± 1.7
Gate I	30.6 ± 0.5	54.0 ± 0.8	17.41 ± 0.9
Gate II	23.0 ± 1.0	75.5 ± 2.1	21.4 ± 2
Gate III	31.4 ± 0.4	37.5 ± 3.2	32.6 ± 3.64

Moreover, in comparison with the air quality between the gates I and III, there was a significant difference/association in the levels of CO_2 , NO_2 ,SO_2 and PM_{10} ($P < 0.01$). However, there was no significant association in the levels of CO, O_3, and VOCs ($P > 0.05$) [Table 4].

Data for comparison of air quality levels between the gates II and III revealed that there was a significant difference/association in the levels of CO, CO_2, SO_2, and PM_{10} ($P < 0.01$). However, there was no significant association in the levels of NO_2, O_3, and VOCs ($P > 0.05$) [Table 5].

In Table 6, with the different meteorological parameters, the dispersion of pollutant was significantly affected by the variability in wind direction, wind speed, relative humidity, and temperature levels, and the most significant factor that modified the levels of air pollutants was the atmospheric stability.

Discussion

High traffic pollution from ship and internal traffic activities inside and outside the port represents a major source of gaseous and particulate air pollutants. From the results of this study, based on the comparison with the Recommended Saudi and International Air Quality Guidelines, the concentration levels of NO_2, SO_2, O_3 and, VOCs surprisingly exceeded the limit in all the sampling stations in the port, while low levels of CO and CO_2 were detected in all the sampling stations.[6]

A recent study revealed that the areas around the port are heavily polluted owing to the emission of ships that used fuel rich in sulfur, emission from industrialized areas, and traffic emissions of NO_2, SO_2, O_3, and VOCs. These findings are in accordance with the studies done by others, which revealed that ambient PM increases owing to ships, contributing to cardiopulmonary and lung cancer risks.[6–8]

Recently, similar studies have addressed the impact of harbor activities on ambient PM levels in nearby areas. In Cargo heavy operations, loading, unloading transport operations, and dust activities that emit higher and uncontrolled concentrations of gaseous and PM levels that have serious consequence effects on human health.[9–12]

The problem of atmospheric stability and meteorological factors can greatly modify the levels of SO_2 and NO_x emitted that transforms into secondary inorganic aerosols, which is mostly deposited on several hundreds of kilometers away from the port to the nearby communities.[13,14]

Higher or lower concentrations of O_3 level emitted from the ship emissions depend mainly on their precursor species (NO_x and VOCs), which may increase or decrease the O_3 formation.[15]

A number of research studies revealed that the atmospheric shipping emissions exhibit serious impact on air quality, where similar results were obtained in the study that highlights the need for intervention control strategy to minimize the pollution impact of KAP and eliminate any health disorders related to the pollution or air quality deterioration.[16,17]

Limitations of the study

This study has limitations that should be considered when interpreting the results.

- Sampling should be done within a longer period (24 h) with more frequency for better precision and accuracy of results.
- Sampling duration should be covering throughout the year to minimize the seasonal variation of the results.

Conclusion

From the data of this study, we concluded that NO_2, SO_2, O_3, VOCs, and PM_{10} levels exceeded the air quality guidelines in all the stations. However, the measured levels of CO and CO_2, were well below the air quality guidelines when compared with the Saudi air quality guidelines.

In addition, the emission of SO_2, NO_2, VOCs, and PM_{10} from the ships and high traffic activities in harbor might induce health problems to workers in the ports in the Eastern Province.

Finally, the need to carry out further more occupational safety and air pollution investigations of the sea port in the kingdom is of greater importance.

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