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RESEARCH ARTICLE

Air Evaluation at Jeddah 1ST Industrial City

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Abstract

Objectives: The study aimed to evaluate Air at Jeddah 1st Industrial City using six pollutants, include nitrogen dioxide (NO_2), ground level ozone (O_3), sulfur dioxide (SO_2), carbon dioxide (CO_2), carbon monoxide (CO) and particulate matter (PM_{10}& $PM_{2.5}$) **Methods:** Methodology of the study focused on site visits of two factories at 1st industrial city including several locations, physical monitoring using approved instrument of Air pollution, data analyzing using specific software, representing the findings in flowcharts and comparing the values to the standards. In order to monitor NO_2, SO_2, CO, O_3, $PM_{2.5}$, and PM_{10} pollutants in first industrial city in Jeddah. **Findings:** Measurements was found that NO_2 and SO_2 exceeded the permissible limits in certain places, the other parameters show good compliance to NCEC limits. These findings, which were confirmed by the COVID-19 lockdown period in Jeddah, show a very significant decline in pollutants and, as a result, a very significant improvement in air quality. This was caused by noticeably lower levels of NO_2 (- 44.5%), CO (- 41.5%), and $PM_{2.5}$ and PM_{10} (- 29.5%, each) than the pre-lockdown average, which were observed in Jeddah, the capital city, during the quarantine. According to the study's findings, the decline in transportation, industrial processes, and other economic activities was significantly associated with the concentrations of pollutants. The global lockdown measures have a negative impact on the main causes of air pollution. **Novelty:** The findings of the current study complement studies conducted during the COVID-19 pandemic, which demonstrated a beneficial reaction to lockdown and show variances in reading measures of the environmental indicators. The outcomes are the first since issuing the standards of NCEC and it shows good compliance. it can also be applied to develop new methods and controls for raising air quality in the future.

Keywords: Air; Pollution; Environment; Saudi Arabia; Jeddah; Industrial Cities; Covid19 Pandemic 3

1 Introduction

In many developing nations, urban air pollution is becoming a significant environmental problem. Because it has an impact on weather, climate, and public health. Particularly in industrial cities, air pollution poses serious dangers to the environment and human health. The World Health Organization (WHO) estimates that seven million lives are lost annually due to air pollution, and that 99% of the world's population lives in areas where air pollution levels are above WHO guidelines for healthy air quality [1]. When discussing the air quality, six criterion pollutants are primarily under focus: carbon monoxide (CO), ozone (O_3), lead (Pb), nitrogen dioxide (NO_2), particulate matter (PM), and sulfur dioxide (SO_2). According to Chhikara and Kumar, et al. [2], ambient ozone (O_3), carbon monoxide (CO), nitrogen dioxide (NO_2), PM10, and $PM_{2.5}$ concentrations are used to determine the quality of the air. Analysis of these air quality measures can reveal variations in the concentration of various air contaminants. Additionally, meteorological factors (such as temperature, wind speed, wind direction, and relative humidity) may have an impact on the concentrations of various air pollutants throughout a specific time [3] . To the best of our knowledge, only a small number of research have been published on the characterization and the effects of (PM_{10}), (NO_2), (O_3), (CO_2), (CO), and (SO_2) on human health in Saudi Arabia, despite the fact that several studies were carried out in the USA, Asia, and Europe.

In order to close this knowledge gap and provide practical solutions to raise air quality in Jeddah and throughout Saudi Arabia, this study was conducted. Due to a shortage of studies on the air pollution in Saudi Arabia, which is currently a health problem for everyone, especially for those working in industries. The major objective of the study was to carry out this measurement, identify the contributing elements, and enhance the air quality in various Saudi Arabian locales. Hassan et al.'s study [4] claims that Riyadh's air quality was compared on a local, regional, and international scale as well as within the city's residential districts. The study showed that a variety of elements is taken into consideration, including working periods, weather seasons, and the COVID-19 period. Lockdown and a drop in activity levels benefited the air quality but hurt the economy.

The Kingdom of Saudi Arabia with a huge transformation along all levels, with sustainability at its heart, Vision 2030 is a catalyst for reform, where the vision was cascaded into strategic objectives to enable effective implementation through vision realization programs, for the environment sector, the National Environment Strategy was launched in 2018 Based on principles of preserving and protecting the environment, conserving its resources and achieving environmental balance. The Kingdom took a historic decision to establish the National Center for Environmental Compliance Control in 2020 as an independent financial and administrative entity that works in integration with the rest of the components of the institutional framework of the national environment system to monitor the compliance of all development activities with approved environmental regulations, standards, and requirements. The center sets environmental controls and requirements and follows up on the enforcement of environmental laws and regulations to achieve the aspirations of wise leadership regarding improving environmental commitment and achieving a balance between development and environmental protection. Due to the lack of environmental academic studies in terms of air pollution in Saudi Arabia and the importance of the industrial sector, this study will the first study for the first time since July 2020 while the limitations of NCEC was issued. Contribute to discovering the level of compliance of one of the industrial cities to the procedures and regulations which described in Table 1 in the way of achieving environmental objectives in the vision of 2030.

Table 1. Air Quality Standards for Primary Pollutants in SaudiArabia [5]

#	Pollutant	Avg. time	Standard ($\mu g.m^{-3}$)	Allowable Access
1	CO	1 Hour	40,000	Once A year
2		8 Hours	10,000	Twice A month
3	NO_2	1 Hour	200	24 Every Year
4		Yearly	100	-
5	SO_2	1 Hour	441	24 Every Year
6		24 Hours	217	3 Every Year
7		Yearly	65	-
8	O_3	8 Hours	157	25 Days Yearly Along 3 Years
9	PM_{10}	24 Hours	340	12 Every Year
10		Yearly	50	-
11	$PM_{2.5}$	24 Hours	35	12 Every Year
12		Yearly	15	-

Jeddah, which has a population of about 3.5 million, is the second-largest city in the Kingdom of Saudi Arabia. It is a beachfront city known as the Bride of the Red Sea that is situated in the midst of the Red Sea's eastern shore and is regarded as the nation's financial and tourism hub. It is the fourth-largest industrial city in Saudi Arabia.

This study was implemented in the south of Jeddah and it aims to evaluate Air of two factories in Jeddah 1st Industrial city with the following objectives:

1. Exploring the literature review in the area of Air pollution
2. Investigate factories by fieldwork in terms of Air pollution
3. Take twenty-four hours of reading measurements of Air at different times and record it
4. Illustrate the data in graphs for each parameter to facilitate comparison
5. Compare the data of the Air parameters to the limitations of the National Center for Environmental Compliance.

1.1 Literature Review

A clean, healthy, and sustainable environment is often regarded as a necessary precondition for the enjoyment of many long-established and universally recognized human rights, such as the right to life, the right to the highest attainable standard of physical and mental health, the right to an adequate standard of living, the right to enough food, the right to a place to call home, the right to safe drinking water and sanitation, the right t These and other human rights cannot be fully exercised when there are adverse environmental effects or harm [6].

The main Parameters Which Effect Air Quality can be classified as Carbon Monoxide (CO): Uncompleted combustion of fuels containing carbon produces the colorless, tasteless, and odorless gas known as carbon monoxide (CO). Without specialized equipment, such as a CO alarm or monitor, CO is challenging to detect. Particulate Matters ($PM_{2.5}$ & PM_{10}): The fact that PM is made up of numerous heterogeneous liquid and solid components, all of which work together to give PM its characteristics, distinguishes the pollutant from gases like nitrogen oxides (NOx) or ozone (O_3). Consequently, a broad range of particle sizes, shapes, surface areas, chemical compositions, and stabilities are included in the definition of PM [7].

Nitrogen Dioxide (NO_2): Nitric oxide (NO), nitrogen dioxide (NO_2), and nitrous oxide are the two main nitrogen oxides that are present in the environment (N_{20}). Since the middle of the 20th century, there has been a steady rise in global NO_x and N_{20} emissions into the atmosphere. Artificial nitrogen oxide (NOx) emissions due to the combustion of fossil fuels constitute more than 75% of the total NOx emissions. This study examines the simultaneous creation of NO_2 and the selective non-catalytic reduction (SNCR) of NOx by methane, ammonia, and urea in the presence of sodium carbonate and methanol. Methane produced N2O levels (18–21 ppm), which were much lower than those produced by urea and ammonia. The NO_x reduction efficiency of methane was enhanced to 40% and 60%, respectively, by the addition of sodium carbonate and methanol. The NO_2 concentration and reaction temperature for the former further dropped to 2-3 ppm and 850-900 °C, respectively. The little differences between the experimental and simulation results were attributable to microscopic factors. Therefore, the study offers crucial recommendations for choosing the top NOx control technology currently accessible [8].

Sulfur Dioxide (SO_2): In the natural world, volcanic eruptions release SO_2. It is present in the atmosphere in one part by parts per billion by volume (1 ppb). The main source of atmospheric SO_2 is the burning of fossil fuels that contain sulfur. It is a significant air pollutant having detrimental effects on both human health and the environment. Acid rain is a result of sulfur dioxide (SO_2) being oxidized in the atmosphere to sulfuric acid.

Ozone (O_3): A significant portion of photochemical oxidants, such as ground-level O_3, are produced by photochemical interactions between nitrogen oxides (NOx) and volatile organic compounds (VOCs) in the presence of light. As a result, meteorological parameters including air temperature and solar radiation intensity, as well as the movement of the contaminated atmosphere, have an impact on the creation of O_3 [9].

Kunt [10] Measures using emission measurements taken from more than 100 industrial units in the area, the air pollution in the unregulated industrial boilers in Kocaeli, Turkey's most industrialized area was assessed. Wang et al. [11] Studied the Particulate matter ($PM_{2.5}$ and PM_{10}) and trace gas (CO_2, NO_2, and SO_2) emissions were measured at different units of the Mugher cement factory and nearby residential areas. Ligia et al. [12] did research At Gazipur City, which is regarded as an industrial city in Bangladesh, the effects of seasonal variation on the atmospheric abundance of gaseous air pollutants (SO_2, NO_2, O3, C_O) and particulates ($PM_{2.5}$ and PM_{10}) were examined. Data on air pollution in the study area were gathered using a Continuous Air Monitoring Station from October 2017 to September 2018.

Tao et al. [13] in his study which the concentration of these pollutants had reached formidably high levels, Kasagici et al. [14] are study at all of the locations, the annual mean $PM_{2.5}$ and PM_{10} concentrations surpassed the Chinese Ambient Air Quality and World Health Organization recommendations requirements, whereas the other parameters showed contrasting outcomes,. 's study the air quality index (AQI) analysis showed unhealthy atmospheric conditions throughout the year for city dwellers

around the study area. Also, Sørensen et al.[15] refer to their study to illustrate how air pollution is diluted and dispersed as a result of both industrial sources and adverse weather. The concentrations of air pollutants on days with more pollution than usual are significantly influenced by meteorological conditions.

Savadkoohi et al.[16] 's study results indicated that (TSP) and gaseous pollutants (CO, CO_2, SO_2, and NO_2) concentration at most sites exceeded WHO standard.

2 Methodology

The instrument from NCEC to collect reading data, Measurement was made using Air Quality Monitoring System (AQM-09) device shown in Figure 1, which were calibrated with methods approved by the National Center for Environmental Compliance.

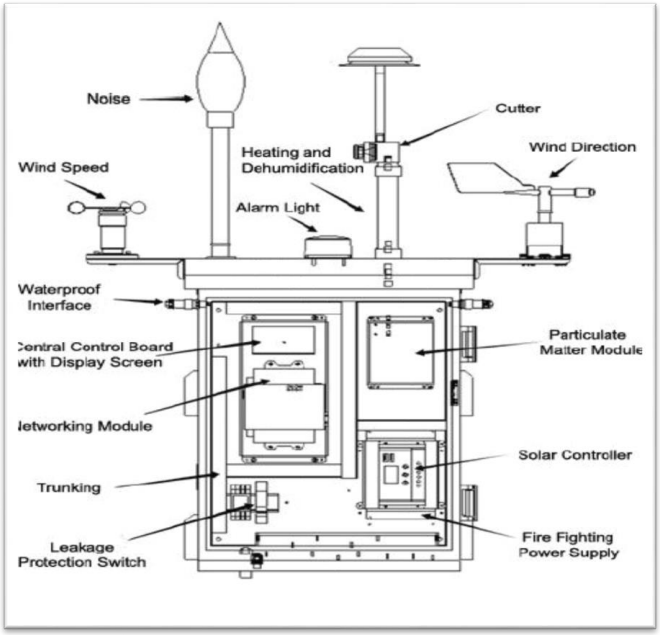

Fig 1. AQM09 Inside Parts

Air Quality Monitoring System (AQM09) were calibrated into an Accuracy $\pm$ 3% F.S and Resolution 0.1 ppm 1 ppb 1 ug/m^3 and response time $\leq$ 30 S and calibration gas test were clarified in Table 2.

Table 2. Cali gas test[17]

Calibration values		
	Gas concentration	**Inspect concentration**
CO	100 ppm	98.9 ppm
NO_2	1000 ppb	996 ppb
SO_2	1000 ppb	998 ppb
O_3	1000 ppb	997 ppb
Measured values		
$PM_{2.5}$	17 ug / m^3	
PM_{10}	22 ug / m^3	

The 1st industrial city has been established at 1971, it is located at the south of Jeddah City with a total area of 12,000,000 m^2, it has a 45 km distance away from king Abdul-Aziz Airport and 15 km into Nearest train station Haramin Station and 13 km far away from Jeddah Islamic Port[18], The factories inside the first industrial city in Jeddah include a different activities This environmental study will be applied within two factories inside the 1st industrial city in Jeddah as it is represented in Figure 2. The activities of factories included in the study are:

1. Liquid Chemical factory
2. Glass factory

Fig 2. Jeddah 1st Industrial City

There were eight monitoring locations chosen around the two factories in the 1st industrial city of Jeddah representing different levels in order to have a comprehensive study of spatial distribution of air. The different visits were inside the boundaries of selected factories which illustrated in Figure 2, These two factories have been chosen to ensure that the gradient extended over a distance of approximately 10 km to cover the 1st industrial city. The visits data are clarified in Table 2. The measurements have taken by the researcher with approved instruments of the National Center for Environmental Compliance (NCEC) Air Quality Monitoring Station.

Table 3. Air Visits Information

Factory	Visit number	Date
Chemical	1	2022 \ 4 \ 5 + 4
	2	2022 \ 4 \ 6 + 5
	3	2022 \ 4 \ 7 + 6
	4	2022 \ 6 \ 13 + 12
	5	2022 \ 6 \ 29 + 28
Glass	1	2021 \ 9 \ 14 + 13
	2	2022 \ 6 \ 22 + 21
	3	2022 \ 8 \ 29 + 28

3 Result and Discussion

3.1 (SO_2)

Figure 3 shows that reading measurements of (SO_2) are in a range between (0 g/m^3 to 5741 g/m^3), and the maximum allowed (SO_2) limit is (441 g/m^3) per (1 hour) according to National Centre for Environmental Compliance (NCEC) Standards of Air Quality Pollutant in Saudi Arabia. According to the National Centre for Environmental Compliance's (NCEC) Standards of Air Quality Pollutant in Saudi Arabia, the Maximum Allowed (SO_2) Limit is (441 g/m^3) per (1 hour).

3.2 (NO_2)

Figure 5 shows (NO_2) over a twenty-four-hour period at five different site visits of the (Liquids Chemical Factory), Standards of Air Quality Pollutant, is 200 g/m^3. It also demonstrates that reading measurements of (NO_2) are in a range between (0

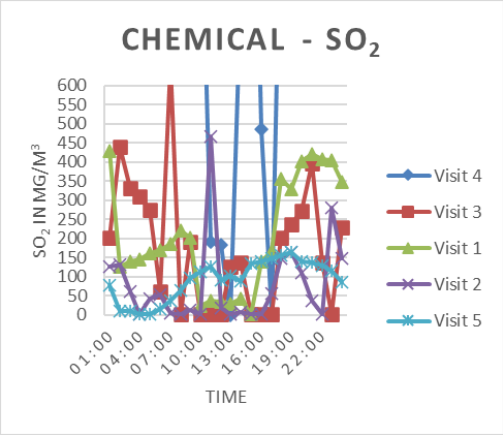

Fig 3. Chemical Factory's 24 Hour (SO_2) Readings

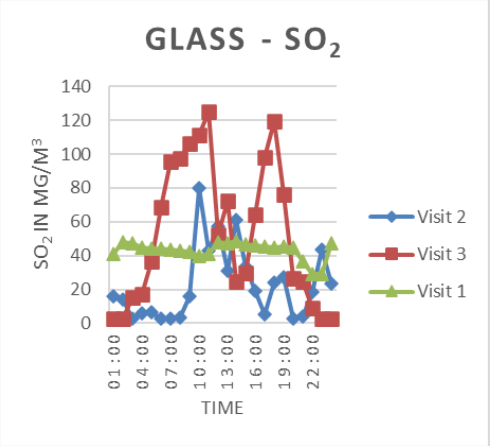

Fig 4. Glass Factory's 24 Hour (SO_2) Readings

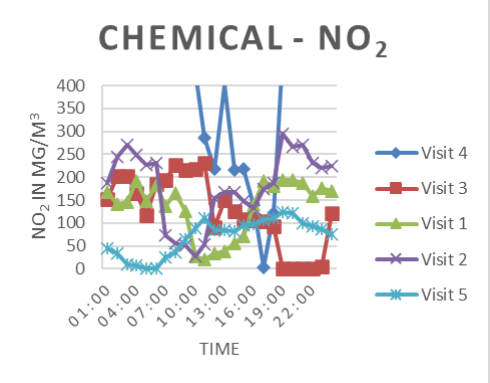

Fig 5. Chemical Factory's 24 Hour (NO_2) Readings

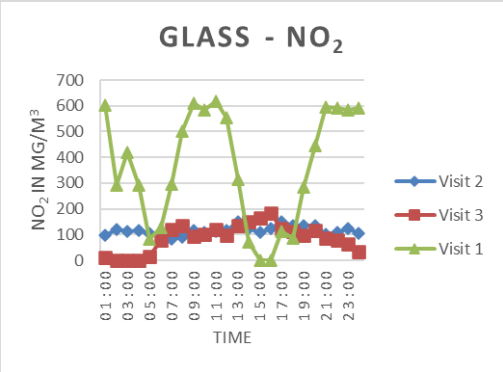

Fig 6. Chemical Factory's 24 Hour (NO_2) Readings

g/m3 to 650 g/m^3), and the Maximum allowed (NO_2) limit is (200 g/m^3) per (1 hour) in accordance with National Centre for Environmental Compliance (NCEC) Standards of Air the limit.

3.3 (CO)

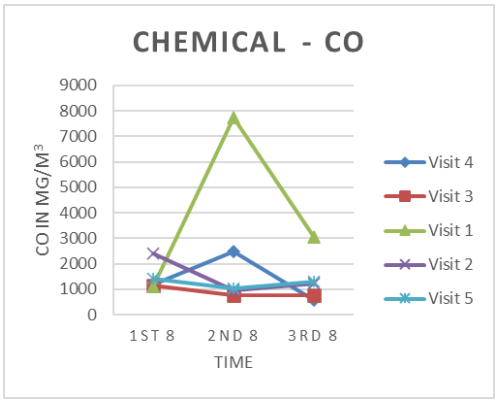

Fig 7. Chemical Factory's 8 Hours (CO) Readings

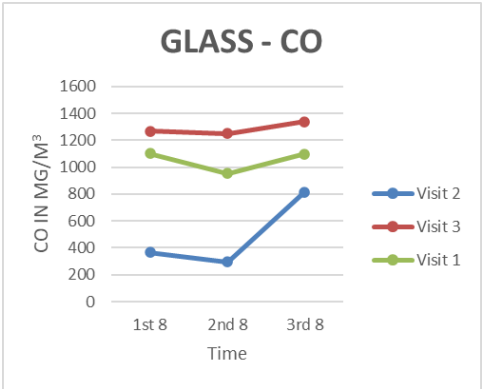

Fig 8. Glass Factory's 8 Hours (CO) Readings

According to Figure 7 (CO) are in the range of (0 g/m^3 to 12000 g/m^3), the maximum allowable (CO) as stated by the National Centre for Environmental Compliance (NCEC), is 40,000 g/m^3 per hour. As shown in the 24-hour reading measurements of

(CO) to five distinct site visits of it demonstrates that the reading measurements of (CO) are in a range between (0 g/m^3 and 8000 g/m^3). The maximum permissible (CO) limit standards of Air Quality Pollutant, is (10,000 g/m^3) per (8 hours).

3.4 (O_3)

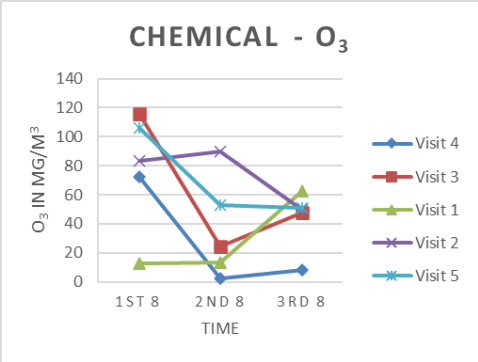

Fig 9. Chemical Factory's 8 Hours (O_3) Readings

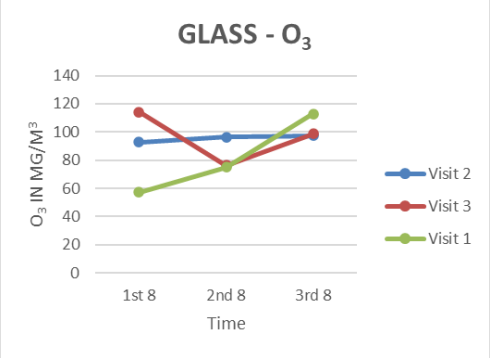

Fig 10. Glass Factory's 8 Hours (O_3) Reading

Figure 9 shows the twenty-four hour reading measurements of (O_3) to five different site visits of (Liquids Chemical Factory), which were observed between (April 2022 and June 2022). This figure represents reading measurements of (O_3) to five different site visits. The maximum allowable (O_3) limit in Saudi Arabia, as stated by the National Centre for Environmental Compliance (NCEC), is 157 g/m^3 per eight hours. The maximum permissible (O_3) limit in Saudi Arabia is (157 g/m^3) per (8 hours), according to National Centre for Environmental Compliance (NCEC) Standards of Air Quality Pollutant.

3.5 ($PM_{2.5}$)

($PM_{2.5}$) measurements of are in a range between (0 g/m^3 to 60 g/m^3), according to twenty-four hour reading measurements to five different site visits of (Liquids Chemical Factory). The maximum allowed ($PM_{2.5}$) limit in Saudi Arabia, according to the National Centre for Environmental Compliance (NCEC) Standards of Air Quality Pollutant, is 35 g/m^3 per (24 hours). ($PM_{2.5}$) taken at three different Glass Factory site visits over the course of the monitoring period of (September 2021 to August 2022). It also demonstrates that reading measurements of ($PM_{2.5}$) fall within the range of (0 g/m3 to 25 g/m^3). The maximum allowable ($PM_{2.5}$) limit in Saudi Arabia, as stated by the National Centre for Environmental Compliance (NCEC), is 35 g/m^3 per 24 hours.

(PM_{10}) measurements for a twenty-four-hour period to five distinct site visits of (Liquids Chemical Factory) that were observed between (April 2022 and June 2022). It also demonstrates that reading measurements of (PM_{10}) fall between 0 g/m^3 and 400 g/m^3. (PM_{10}) limit in accordance to the National Centre for Environmental Compliance (NCEC) Standards of Air Quality Pollutant, is 340 g/m^3 per (24 hours). Measurements of (PM_{10}) to three different site visits of (Glass Factory) that were observed between September 2021 and August 2022, also demonstrates that reading measurements of (PM_{10}) fall within the

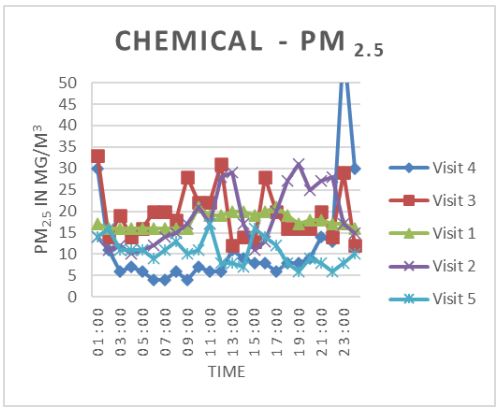

Fig 11. Chemical Factory's 24 Hours ($PM_{2.5}$) Readings

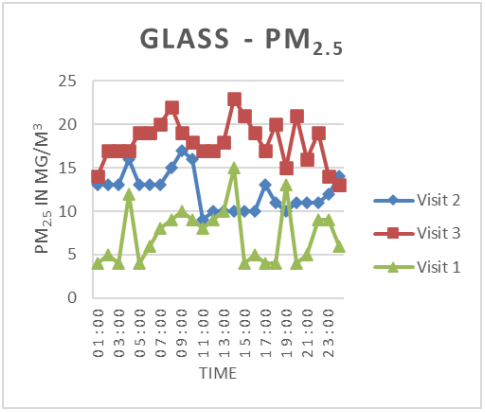

Fig 12. Glass Factory's 24 Hours ($PM_{2.5}$) Readings

range of (0 g/m3 to 200 g/m^3). The maximum permissible (PM_{10}) limit in Saudi Arabia, according to the National Centre for Environmental Compliance (NCEC) Standards of Air Quality Pollutant, is (340 g/m^3) per (24 hour). As it can be seen, visits (1, 2, and 3) fall inside the acceptable limit range.

3.6 (PM_{10})

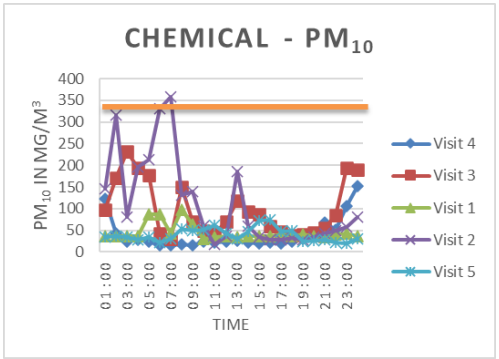

Fig 13. Chemical Factory's 24 Hours (PM_{10}) Readings

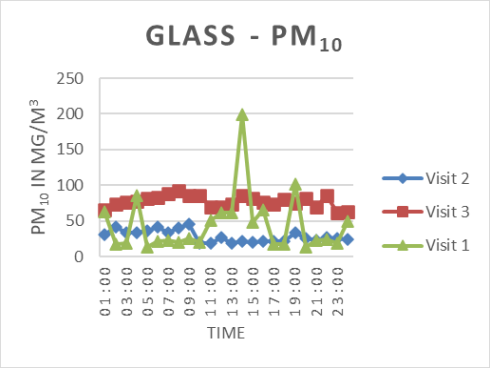

Fig 14. Glass Factory's 24 Hours (PM_{10}) Readings

There are variation in results of nitrogen dioxide (NO_2), ground level ozone (O_3), particulate matter (PM), carbon dioxide (CO_2), carbon monoxide (CO) and sulfur dioxide (SO_2) (PM_{10}) , and ($PM_{2.5}$) in different reading with different periods . These results confirmed with The daily temporal variations of PM10,$PM_{2.5}$, carbon monoxide (CO), nitrogen dioxide (NO_2), and ozone (O_3) were used to investigate the changes in air quality in response to COVID-19 lockdown control measures from January to December 2020 in Jeddah, Saudi Arabia. Meteorological parameters (wind speed, direction, temperature, relative humidity) were also analyzed to understand the changes during the pandemic. As a result, significant reductions in the concentrations of NO_2 (– 44.5%), CO (– 41.5%), and $PM_{2.5}$, PM_{10} (– 29.5%, each) were measured in the capital city of Jeddah during the quarantine compared to the pre-lockdown average (Kumari et al,.)[19].

To the best of our knowledge, this study provides the first comprehensive analysis of the variations in $PM_{2.5}$, PM_{10}, CO, NO_2, and O_3 concentrations before, during, and after the lockdown in Jeddah, Saudi Arabia. The results of the present study clearly show that exhaust emissions from vehicles and industrial plants were tremendously decreased when the Saudis were enforced to be home quarantined to curb the virus spread. As a result, their rate of entry into the atmosphere was reduced. Generally, curbing anthropogenic activities could improve air quality. Tang et al.[20] confirmed the reading measurements with data collected during the COVID-19 pandemic, and they showed this increase in O_3 levels to the reduction in NO_2 levels. It clearly shows that the lockdown measures had a positive effect on air quality around the world. All pollutants studied exhibited significant reductions during the lockdown, with the exception of O_3. Moreover, recently, Stearns et al.[21] found that the reduction in concentrations of pollutants was significantly ($p < 0.01$) correlated with the decrease in transportation, industrial processes and other economic activities in Egypt. The main contributors to air pollution were adversely affected by the lockdown measures worldwide (Bauwens et al. 2020; Feng et al.; Viteri et al.[22]. The results of the present study are consistent and in agreement with previous studies that travel, restrictions during the lockdown caused the most significant reduction in NO_2.

4 Conclusion

The study shed light on the effects of environmental pollution in the industrial city and its impact on public environmental health and workers in factories. Current study on air pollution and human health, particularly for those who work in the study area's target population, Through a sample of two distinct activities, two different site visits, and a survey of the air parameters NO_2, SO_2, CO, O_3, $PM_{2.5}$, and PM_{10}. This paper evaluated the air pollution in Jeddah industrial City, particularly the first industrial city in Saudi Arabia, which has a variable amount of industrial activities in western region of Saudi Arabia. The basic requirements of the study were obtained through field visits and based on various monitoring devices to detect and compare emissions.

The time series for PM_{10}, $PM_{2.5}$,CO, and NO_2 during quarantine showed a clear reduction of pollutant concentrations which is directly associated with anthropogenic emissions. The targeted emission controls significantly improved air quality in the city. The variation if environmental indicators measurement reading confirmed with results of study carried during COVID-19 in Jeddah city ,where the variations of PM_{10}, $PM_{2.5}$, carbon monoxide (CO), nitrogen dioxide (NO_2), and ozone (O_3) changes in air quality in response to COVID-19 lockdown control measures study carried in Jeddah 2020, Saudi Arabia. As a result, significant reductions in the concentrations of NO_2 (– 44.5%), CO (– 41.5%), and $PM_{2.5}$, PM_{10} (– 29.5%, each) were measured in the capital city of Jeddah during the quarantine compared to the pre-lockdown average.

According to the pointed-out results of the study, the researcher recommends:

1. Periodic internal auditing for the factories to be inside the accepted boundaries of pollution according to the National Centre for Environmental Compliance (NCEC) by providing the approved instrument or hiring an approved Laboratory to provide the required tests.
2. The importance of maintaining and calibrating the factory equipment periodically to ensure a high level of efficiency, which helps, reduce the emissions of different air parameters.
3. There is a need for awareness campaigns using advanced awareness methods that help the working community to keep pace.
4. Conduct further studies to evaluate the environment and the effects of pollution.
5. Since the evaluation of air quality highlights, the significance of ongoing work to maintain a healthy and sustainable environment, researchers must continue their studies in Jeddah 1st industrial city, by putting the study's recommendations into practice we can improve air quality.

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